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A CHART OF THE PSYCHOMETRIC FUNCTION

By Edwin G. Boring

In a drill course in the psychophysical methods the instructor has often to face the problem of making the form of certam mathematical functions intelligible to students who have only the competence afforded by the ill-remembered contents of a high school algebra. In the Cornell Laboratory we have utilized the principle of the 'coin problem'[1] to construct a chart, which (1) accounts for the form of the curve of error, (2) indicate. the manner in which the *phi*-function of *gamma* depends upon the curve of error, and (3) shows, in the light of these derivations, why the Φ (γ)-hypothesis provides a plausible equation for the psychometric function,—all without the use of more mathematics than the simplest algebra. It is true that some arbitrary assumptions are necessary, but they do not, we believe, offset the pedagogical gain of simplicity. We reproduce the chart herewith. Its exposition is as follows:

Let us take as our typical problem the determination of the limen of dual impression upon the skin. The original formulation of this problem (Fechner) required that we discover what value of the stimulus in cm. (separation of the aesthesiometer points) is necessary just barely to elicit the impression 'two.' In practice, however, very different values of stimulus sometimes give rise to the impression 'two' and sometimes not, so that there is no fixed point of change. We may nevertheless conceive as fixed *at any given moment* a point of

[1] See, for example, L. D. Weld, *Theory of Errors and Least Squares*, 1916. 41-51 To the unmathematical psychologist, who would nevertheless become psychophysicist, this book can not be too highly recommended!

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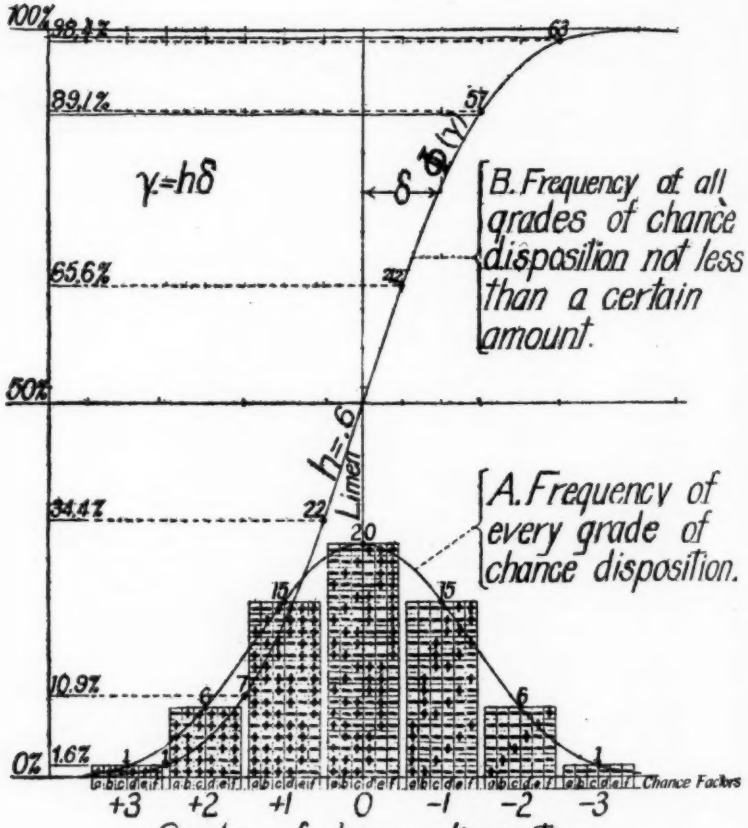


CHART OF THE PSYCHOMETRIC FUNCTION

change above which a stimulus would give the impression 'two' and below which it would not, provided that we do not forget the essential fact that this point is fixed only for the moment. The stimulated organ, we may then say, is variously disposed for impression,—a variation of disposition which occurs independently of the value of the stimulus, and as the result of the interplay of a large number of factors that work by chance, whenever the stimulus is applied, for or against the impression 'two.'

Ideally, in a psychophysical problem, we are concerned exclusively with a correlation between stimulus and impression. We presuppose an accurately controlled stimulus, an unvarying receptive apparatus the stimulation of which gives us the impression, and a mechanism that provides a report exactly reflecting this impression. Since, however, even in a careful experiment, we can control the stimulus only within the limitations of physical appliance, and the report only in so far as the observer can maintain constancy of attitude, we can never quite realize these ideal conditions. For the present, however, we shall overlook the possibility of departures from ideal conditions. We shall see, when we have finished our discussion, what part such departures may actually play in psychophysical work.

Let us suppose that there are, in connection with the organ of sense, just six factors, every one of which may dispose either toward or against the occurrence of the impression 'two' and therefore of the judgment 'two;' and let us call them *a, b, c, d, e,* and *f*. Further, let us represent a disposition toward the impression 'two' by "+" and a disposition against 'two' by "—". We assume that every factor disposes either toward or against the impression 'two' and never operates intermediately; and that the occurrence of "+" or "—" is independent of the stimulus and determined entirely by chance.[2] We have the possibility of seven grades of total disposition depending upon the chance occurrence of *pluses* and *minuses* for the six factors. (1) There is a single possibility that all six factors will dispose toward the impression 'two.' Let us call this grade of chance disposition "+3." It is indicated by the six concurrent *pluses* over the abscissa-value for "+3" on the chart. (2) There are six possible cases in every one of

[2]Actually we should need to assume an infinite number of factors or an infinite number of degrees of disposition; but we must keep our numbers finite or we shall complicate exposition.

If one wishes to think of "—" as the absence of a positive disposition rather than as a negative disposition, the argument is not altered.

which are five *pluses* and one *minus*,—a grade of chance disposition next less favorable to the 'two'-impression ("+2" on the chart). (3) There are fifteen possible ways in which four factors may dispose for and two against the dual impression, a chance disposition of "+1" (see chart). (4) The dispositional condition called "0" on the chart occurs when three factors dispose toward 'two' and three against; there are twenty such possible cases. When the *minuses* predominate, we get, in like manner, (5) fifteen cases for the negative disposition (against the impression 'two') of "—1," (6) six cases for "—2," and (7) a single case of maximal negative disposition, "—3." If we join these points we get the curve of error, which is marked "A" on the chart, and which gives the frequency of occurrence of every grade of chance disposition.[3] The familiar bell-shape of the curve represents the fact that there are more possible combinations of the chance factors when these are half and half unlike in effect than when they are all alike; and, further, that, in the region midway between these two conditions, the number of possible combinations decreases most rapidly.

The curve "B" is derived from "A". It shows the frequency of occurrence of all grades of chance disposition not less than (equal to or greater than) certain amounts. For instance, for the disposition called "+3" there is only the single case of the six *pluses* in which the stimulated organ is disposed for the impression 'two' by an amount not less than "+3." There are seven cases in which the dispositional grade is not less than "+2" (six in which it equals "+2" and one in which it is greater); there are 22 cases in which it is not less than "+1" (15 in which it is equal, 6 + 1 in which it is greater); and so on, with 42 cases (20 + 15 + 6 + 1) in which it is not less than "0," and 57, 63, and 64 cases in which it is not less than "—1," "—2," and "—3" respectively. Thus every point on the B-curve is the sum of all cases which lie to the left of it, as represented under the A-curve. The total number of cases is 64. If every sum is expressed as a percentage of the total number of cases we get the ordinate-scale at the left of the chart: 0, 1.6, 10.9, 34.4, 65.6, 89.1, 98.4, and 100%.

This B-curve is symmetrical about the 50%-line and would, if we had not arbitrarily taken a finite number of cases, be asymptotic to the 100% and 0% lines. It is known as the *phi*-function of *gamma*, $\Phi(\gamma)$, γ is a general unit of abscissa defined as the product $h\delta$, in which h is the measure of pre-

[3] Thus we may compute the ordinates by a formula for permutations; Weld, *op. cit.*, 42.

cision of both the A- and B-curves, and δ is the distance of any point on either curve from the ordinate of symmetry (in this case, the ordinate for balanced dispositional factors, the zero-ordinate on the chart).[4]

So far we have dealt only with the factors which vary by chance. The B-curve is merely an expression for the frequency with which dispositions toward the impression 'two', not less than certain amounts, occur by chance. But the controlled value of the stimulus also disposes more or less toward the impression 'two.' This impression will actually occur whenever the controlled disposition, dependent upon the value of the stimulus, and the total disposition of the receptive organ, dependent upon chance, are together adequate to the impression 'two.' The less the separation between the aesthesiometer-points, the greater must be the chance disposition of the organ, if the impression 'two' is actually to occur.

Suppose now that 1.2 cm. in the stimulus is critically adequate[5] to the impression 'two' whenever it occurs with the grade of chance disposition which we have called "0." Let us write "1.2" under "0" on the chart. A lesser stimulus, 1.1 cm., would require a greater chance disposition to be critically adequate to the impression 'two.' Let us say that 1.1 cm. is critically adequate when it occurs with the grade of chance disposition called "+1," and let us write "1.1" beneath "+1" on the chart. Then we may expect that 1.0 cm. will be critically adequate whenever it occurs with a chance disposition of "+2"; and so on. Thus we write under every grade of chance disposition the value of the stimulus which, in concurrence with that grade of chance disposition, would attain critical adequacy to the impression 'two.'

It now appears that we shall get the impression 'two' for a given stimulus whenever the grade of chance disposition which renders the given stimulus critically adequate to that impression occurs, or whenever there is a still more favorable grade of chance disposition. The B-curve shows the frequency of grades of chance disposition not less than given amounts; that is to say, the B-curve gives, when taken in relation to the scale of stimulus-values, the frequency with which a grade of chance disposition adequate to the impression

[4] For the use of these terms in the method of constant stimuli, *cf.* E. G. Boring, Urban's Tables and the Method of Constant Stimuli, *Amer. J. Psychol.*, 28, 1917, 281-285.

[5] By the phrase "critically adequate" we mean, in this discussion, to indicate the value which is the point of change from inadequacy to adequacy. We do not intend the Fechnerian notion; the point that is "critically adequate" is neither adequate nor inadequate, but is the point of change.

'two' will occur; or, more simply, the frequency of the 'two'-impressions for any value of stimulus. Thus, if we were to apply to the skin at random these values of the stimulus and were to record the frequency of occurrence of the judgment 'two' (which, we have assumed, corresponds exactly to the frequency of the impression 'two'), we should expect this curve of frequencies to be identical with the curve of dispositional chance factors (the B-curve), provided, of course, that our assumptions have been correct. The B-curve is, as we have seen, the $\Phi(\gamma)$; and a curve that gives frequencies of judgment as a function of the magnitude of stimulus is known as a *psychometric function*. Hence it follows that, under our assumptions, the $\Phi(\gamma)$ is the psychometric function.

We are now in a position to get some notion of what is meant by a *limen*. In practice, when we obtain empirically a set of data which approximate the $\Phi(\gamma)$ (the B-curve), we take the stimulus-value corresponding to the 50%-point of this curve as the limen. This is also the maximal point of the curve of error (the A-curve). The limen is, therefore, the value of stimulus which is critically adequate to the impression 'two' (hence the judgment 'two') whenever it occurs with the most frequent value of chance disposition; or, more simply, the limen is the stimulus which is most frequently critically adequate to the impression 'two.' Furthermore, we may note that the most frequent chance dispositional condition thus occurs when chance factors balance or cancel one another.

We began this discussion by making certain assumptions and we have argued that if these assumptions were valid the $\Phi(\gamma)$ would be the psychometric function. In practice, on the other hand, we find our psychometric functions empirically and then determine how closely they approximate the $\Phi(\gamma)$. We get, in practice, considerable agreement between hypothesis and fact; hence it appears that our assumptions are approximately valid.

Does this agreement between fact and theory also assure us that the value of the stimulus is accurately determined by the setting of the physical instrument and that the impression is exactly represented by the judgment? Not necessarily; it means that the errors which occur in either of these ways are relatively small, or are constant, or, perhaps, are due to chance. If small, they alter the limen by a negligible amount; if constant, they alter it by a fixed amount; if due to chance, they merge with the other chance factors and do not change the limen at all, although they may decrease its precision.

AN IMPROVED METHOD OF USING THE TELEGRAPHIC REACTION KEY

By HAROLD A. RICHMOND, Wesleyan University

As commonly used, the telegraphic key is not an entirely satisfactory reaction device. In the first place, there is the minor objection that it is not conveniently portable. It cannot be easily and quickly transferred for use in different places. If similar experimental conditions are maintained, the key must always be used at a constant height. Consequently, the table or stand on which it is placed must either be moved with the key, or a new stand of the same height must be provided for a different position of the subject. A more important objection is the fact that the release of the key may be brought about by a variety of possible forms of response. A mere lift of the finger will release the key, but the release may also be made by raising the hand, the forearm, the whole arm, or even by a movement of the body. From the use of the single pair of muscles involved in lifting the finger, the response may spread to the use of various combinations of large sets of muscles. As one set of muscles becomes relatively fatigued in making the reaction movement, another set may be brought into play. The importance of making the reaction movement as simple and uncomplicated as possible and of limiting it always to the same set of muscles needs hardly to be emphasized. Unless such a uniformity of conditions is obtained, the responses in successive reactions may be widely diverse in character. Under such circumstances we have no way of knowing whether a variation in reaction time is due to a change in the mode of response, or to a change in some other conditions influencing the reaction. One is not measuring homologous events.

Experimental analysis by Judd[1] and earlier work by W. G. Smith[2] has shown that the reaction movement with the ordinary use of the telegraphic key may be preceded by a sudden antagonistic movement, as well as various changes in pre-reaction muscular tension. Judd used a spring-supported key

[1] *Yale Psychological Studies*, I, (N. S.), p. 141.
[2] Mind, XII, (N. S.), p. 47.

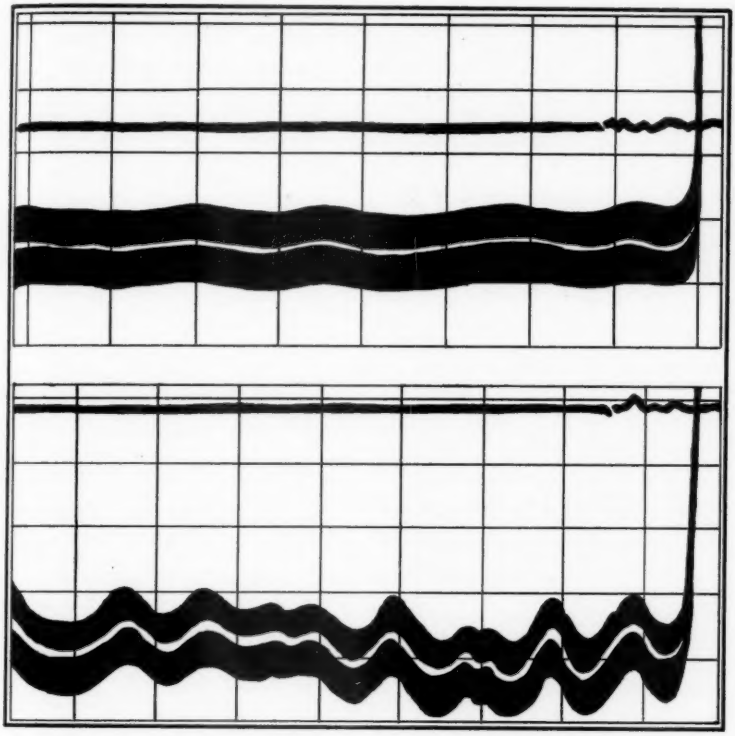
without arm rest. He found, however, that the antagonistic movements could be eliminated by requiring the finger to press upward against a second spring during the period of preparation. Since, as Judd's investigation shows, the reaction time is varied considerably by these antagonistic movements, they should if possible be eliminated.

The use of the telegraphic reaction key as developed in the Wesleyan Laboratory and here presented involves the suspension of the key, as a pendulum instead of on a spring, and employs the opposition of the thumb and fingers in producing the reaction movement. An ordinary telegraphic key mounted on a light wooden base is suspended so as to hang in front of the subject at a height at which the reactions can be most comfortably made. Generally, the same height as the elbow is the most satisfactory. The key is closed by placing the finger on the button and the thumb on the back of the wooden base, and pressing them together. By simply opening thumb and finger, the key is released. In point of view of its suspension and the employment of both thumb and finger, it resembles the modified form of the Dessoir reaction key devised by Scripture,[3] and has all the advantages of portability claimed for the latter. Instead of requiring thumb and finger to open in a vertical plane, as is the case with Scripture's key, the suspended telegraphic reaction key allows a horizontal motion of thumb and finger which is rather more natural and easier. Moreover, in Scripture's key the thumb is held in a relatively fixed position and plays no part in making the response movement. Furthermore, in making the response movement, the finger must move a mass and overcome a variable amount of friction. The suspended telegraphic key allows the thumb to move naturally and freely, and offers no resistance to be overcome by the finger.

With the use of the suspended telegraphic reaction key, the number of muscles which may be used in making the response movement is reduced to the fewest possible, viz., the set of muscles involved in the opposition of thumb and finger. By the use of these muscles and these alone can the key be released. Movements of the wrist, arm, or body cannot replace the reaction movement, nor retard it by an antagonistic movement. By thus confining the response to the action of a single set of muscles, one source of possible variations in reaction time is removed.

[3] *Yale Psychological Studies*, 1893, p. 88. See also Titchener, Experimental Psychology, 1905, II, Part I, p. 165.

FIG. 1



MICRO-PHOTOGRAPHIC RECORDS OF REACTION MOVEMENT SUPERPOSED ON MUSCLE TREMORS. (MAGNIFIED 250 TIMES.)

Another factor to be noted in connection with the use of the suspended telegraphic key is that it apparently eliminates the antagonistic reactive movements described by Judd. Enormously magnified graphic records of the reaction response gave no indication of such movements. In Figure 1 are shown reproductions of photographic records of the muscular changes in thumb and finger, before and during the response. These records were obtained by photographing the optically magnified movements of a fine silk fiber made to move in exact

correspondence with all rapid changes in muscular tension preceding the reaction movement. In taking these records, the regular telegraphic key was replaced by a small rubber bulb, which the subject pressed between thumb and finger and released in exactly the same way as he would the regular key. This bulb was connected by tubing to one end of a closed cylinder, the other end of which was covered by an elastic membrane, making a small Marey tambour. Any changes in the volume of the bulb with consequent changes of pressure in the cylinder would cause the membrane to move back and forth correspondingly. Attached to the membrane was the silk fiber, the movements of which, magnified 250 times by a projection microscope, were photographed by a falling plate camera.[4]

A sharp sound served as the stimulus to which the subject reacted, and the moment of giving the stimulus is shown by the break in the small line at the top of the record. The release of the bulb in the reaction response produced such a large movement of the fiber that it was carried completely off the plate, in spite of a vent to prevent rupture and eliminate slow pressure changes.

The device for transferring changes in pressure between thumb and finger to movements of the silk fiber was one of great delicacy. Relatively large movements of the fiber image resulted from very slight changes in pressure on the bulb. Muscle tremors and variations in muscular tension are conspicuous on the records. The records shown in Figure 1 are samples of two general types of records obtained in the experimental tests. In the upper record, the muscle tremors and changes in muscular tension during the preparatory interval are relatively slight; in the lower record, these variations are more emphasized. The different types were not limited to different subjects. From the same subject we obtained both smooth and wavy records in apparently chance succession.

Not one of our twenty odd records from four subjects shows any reactive antagonistic movement like those found by Judd. Judd finds a satisfactory explanation of the reactive antagonistic movements difficult, and ventures the opinion that they are due to a diffusion of the motor impulse which conditions the response. If such is the case, how are we to explain the disappearance of these movements when the subject reacts against the resistance of a spring, or by opening thumb and finger, as in the use of the suspended telegraphic key? A

[4] For a description of the falling plate camera see Dodge and Benedict, The Psychological Effects of Alcohol, 1915, p. 79.

possible explanation is that the sudden antagonistic movement is the result of a downward thrust of the finger to aid in the movement of the arm upward. Movement of the arm from the elbow means that the muscular contraction has to work against a long leverage. A slight downward push of the finger is certainly a great aid in getting the movement of the arm started, and is a natural mode of response. When, however, the finger is pressing against a resistance from above, any downward movement of the finger cannot aid in overcoming that resistance. Consequently, such a movement, being entirely useless, would be eliminated from the muscular response. It would be interesting to know whether those subjects in Judd's experiments who tended strongly to giving the antagonistic reactive movement did not also predominantly tend to use the arm in making the reaction movement. If such be the explanation of the antagonistic reactive movements as found by Judd, then it is not difficult to explain their disappearance in the use of the suspended telegraphic key, for this entirely eliminates the possibility of that form of response.

Furthermore, both mechanically and biologically, there seems to be no reason why the movement of opening the finger should be preceded by a movement in the opposite direction. But one set of muscles are involved in making the response, and it is hard to conceive how the contraction of a set of muscles would be aided by a preliminary contraction of their antagonistics. The upward movement of the arm, however, is directly aided by a preliminary downward thrust of the finger. Biologically, the opening of the thumb and finger is a natural movement, the movement of releasing something painful and injurious to the organism. It would be contrary to biological precedents if the movement of releasing an injurious object, such as a hot coal, for example, should be preceded by a movement to hold it more firmly. In any event, all the evidence at hand argues against the possibility of the reaction movement being preceded by a sudden antagonistic movement, in the use of the suspended telegraphic key.

The fact that the suspended telegraphic reaction key may be quickly and easily transferred for use wherever desired, requiring only some support for suspension, the fact that it limits the reaction movement to the action of a single set of muscles, and the fact that it eliminates an antagonistic reactive movement from the response combine to make its use an improvement over the reaction key as it is commonly employed.

SOME STRIKING ILLUSIONS OF MOVEMENT OF A SINGLE LIGHT ON MOUNTAINS

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It is now well known that our visual perception of any object in nature is determined not only by the rays of light from the objects that impinge upon the retina, but also by numerous other factors. Seeing is not a process of some "mind" looking out through the eyes upon the objects. The objects perceived are not so simply given in the objective world. Perception is quite a different process from such a passive procedure. This fact is more easily recognized in auditory than in visual perception. It is obvious that when we hear the robin outside in the spring we must be associating, though not consciously, visual factors with the sound, or how could we know that the sound is that of a bird of a certain color, size, and in a certain location? One also easily understands that such matters as the position of the head and the relative strength of the stimuli coming to the two ears are important in our determination of the direction of the source of the sound.

A large variety of factors has been shown to be of importance in visual perception. The story of the scientific advance in this field makes a chapter of real gain in the history of psychology. The location in the visual field of a dot on the wall, for instance, is determined in part by the position on the retina which it stimulates, or on which its image falls. If the dot is near the ceiling in front of one it stimulates the lower part of the retina; if it is at the right its image falls on the left portion of the retina; and so on. In consequence of this simple result of having a lens, the image on the retina of any perceived object, as is well known, is inverted. The old question of how the image becomes "turned right side up again" in getting to the cerebral cortex, or the "center of vision," is nonsense, and reveals a total misapprehension of the matter. No image is thus transmitted at all, but rather every part of the area of the retina stimulated is to be thought of as a particular case of the general law of the location of visual objects to which reference is made in

the early part of this paragraph. The tendency is to locate any object stimulating the retina, along the line determined by the point stimulated and the nodal point on the lens through which the ray passes. Since any point on an object stimulates a particular point on the retina, the various tendencies are co-ordinated in a way to give a total percept of the object —a certain shape, outline, volume, direction and distance consciousness.

The eye tends reflexly to turn so that the image of any stimulating dot falls on the fovea. Whether this tendency is wholly innate or is partly acquired, is not fully known. Or, better, how far the innate tendency is modified by experience in various animals and in man is a matter that is not settled. Certain innate reflex tendencies to eye movements of this kind are not to be doubted in some species of animals.

This suggests, too, that the eyes are not stationary with reference to any given position of the head, and the head is not determined by any given fixed position of the body. The direction of the visual object is therefore determined not only by the place of stimulation on the retina—for an object may be seen to move even though the eyes are fixed on it and are moving with it, in which case the image does not move across the retina—but also by numerous kinesthetic sensations. Normally various other factors are also important in the location of a moving object, such, for instance, as the images of other things over which the object is passing.

It is obvious, moreover, that all the diverging rays from any dot in the visual field must be brought to a focus on the retina, otherwise the effect would be that of a faint stimulation of the entire retina and the stimulations of several objects would all be superimposed and in no case distinguishable. This is the same thing as saying that the objects would appear blurred, or completely fused together. This focusing of all the diverging rays from any particular point in the visual field is effected by the refraction of the light rays as they pass through the lens. This requires careful adjustment of the lens for different distances, an adjustment that is brought about involuntarily by contractions or relaxations of the ciliary muscles. It must also be remembered that the perception is binocular. Therefore movements of co-ordination of the two eyes must play an important part. Any irregularities in any one of all these processes, due to fatigue, to unusual strain, or to pathological conditions must, of course, interfere with vision. Of such interferences resulting in illusions of different kinds and degrees Dr. H. A. Carr

has given and discussed a number of illustrations.[1] Illusions of depth have been known in some cases to be under voluntary control, as are also occasionally the clicks produced in the ears when swallowing, by the contractions of the tensor tympani muscles.

The perception of distance, or of depth, is dependent upon a large number of associated factors, such as color (since colors change with distance), clearness of outline, brightnesses and shadows, superposition of near objects on farther ones. Then, too, some more definitely kinesthetic factors, or impulses from muscular activity, play an important rôle: the apparent size of objects whose size is known, the relative size of various objects at different distances, and the apparent rate of movement of objects whose rate is fairly well known. A description of the rôle in perception of each of these factors would lead us too far from our special purpose. They are merely mentioned here to suggest the extreme complexity of visual perception.

Yet it must be emphatically stated here that perception is not a logical process, or even a matter of judgment, at all. We do not take note explicitly of all, and usually not of any, of these factors and then *conclude* that the object is located in such and such a direction at a distance of about thirty feet! This happens only when perception somehow misleads us. The whole process of perception is immediate. Instead of seeing in the distance a person known to be six feet high, noting that he appears very small, that some nearer objects conceal part of him as their outlines overlap his, that though walking he seems to move very slowly, that the outline of his figure is vague, that the strains of our ciliary and inner recti muscles are very slight, and so on, and then judging that he is so many blocks away, slightly to our right,—instead of such a deliberate process we immediately see him in a certain direction and at a recognized distance. The whole situation flashes into consciousness instantaneously, and does not come by any sort of inferential process whatever. This is what makes illusion not only so easy but so absolutely deceptive and stunning. We, of course, experience numerous minor and partial illusions which never are recognized as such. This is no doubt true with respect to any of the senses. It is really only when confusions and inconsistences arise in our experiences that our attention is drawn to certain imperfections in perception. Even in such cases analytic studies

[1] *Psychol. Rev. Mon.*, Vol. VII, No. 3; *Psychol. Rev.*, XIII., 258; *ibid.*, XV., 139; *ibid.*, XVI., 219. References to other writers are given.

in the psychological laboratories are necessary as a rule for a full understanding of the illusion.

The illusions now to be described are so interesting in themselves and cast so much light on certain larger problems of our orientation that it is thought worth while to report them, even though they were experienced so long ago that on many details where record is incomplete a high degree of accuracy in description is not possible. One of the illusions occurred in the writer's childhood and is purely a matter of memory Only matters about which there is a high degree of certainty are given, however. The other illusion is a matter of record, but many of the details as to rate and direction of movement, the time for the illusion to develop, and so on, are lacking, some of the problems relating to which having been developed more recently in researches. It is hoped that the report, with such imperfections as it may have, may lead to the obtaining of more careful descriptions of similar illusions by those who chance to observe them.

On a dark rainy evening in December, 1909, from about 8 to 10 o'clock, a visual illusion of motion of striking proportions was witnessed by two high school students and four adults, two men of the latter being college students and the others being the writer and his wife. The illusion consisted in seeing movements of a stationary light on a mountain east of Provo, Utah. It first came to the attention of the writer and he called the other persons to witness the phenomenon. The part of the Wasatch Range on which the light was located is nearly directly east of the north side of the city. The observers were viewing the light from a position in the northeast part of the city, the house being located on a corner of Fourth East and Seventh North streets. The visible portion of the mountain on which the light was located has a height of about 1,000 meters (3,280.8 ft.) above the point from which the observation was made, and from this point an air line to the light, which was approximately half way up the mountain side, is about 2,000 meters, or something over a mile. The intense darkness of the night made only the outline of the mountain visible, the whole side from base to top being a perfectly dark field. This condition is well known to be most favorable for the illusion.

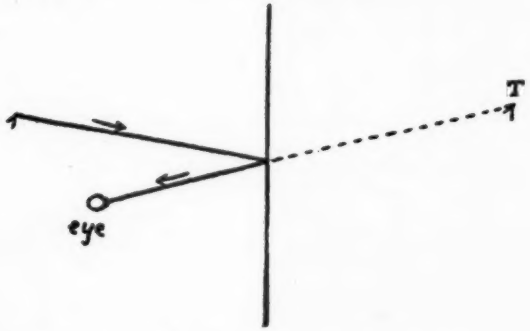
The writer watched the light some time himself before calling out the other observers. The phenomenon was really wonderful. One acquainted with mountain climbing knows that it is a slow, tedious process; yet here was a small, brilliant light, presenting much the appearance of a distant lan-

tern, moving about on the mountain side with an amazing speed. The light was, of course, larger than an ordinary lantern so far away would appear. The movements were very irregular, now and then presenting the appearance of one hesitating to think which direction to follow, *i. e.*, the movements were very much like the voluntary behavior of an individual rather than like some mechanical process. Frequently the light would, after such apparent deliberation, suddenly shoot out in a certain direction at a great speed. These extensive movements were always more or less up or down, frequently going obliquely to the sides in a direction making an angle not to exceed 30 or 40 degrees with a vertical line. Often it would seem to approach the upper edge of the mountain's outline, or, if going in the other direction, its base; but it, of course, regularly stopped and moved back. The backward movements were seldom, if ever, a direct retracing of the other path; *i. e.*, if we call the movements away from the true position of the light the out-movements and those bringing it back the in-movements, it could be said that seldom would the in-movements retrace even a part of the out-movements. The larger shooting movements were moreover, not usually uniform in direction, but they were frequently subject to smaller irregularities. For instance, the light might shoot rapidly up slightly to the right and then turn somewhat at a particular place to this side or that; it might then pass downward in a more nearly perpendicular direction, and then up toward the original position. It should also be noted that occasionally movements up or down might go on for a short time without seeming to bring the light nearer the edge of the mountain; this, it seems to me, was particularly true when the attention was directed to the edge with a question as to how soon it would be reached. The light always stopped or changed direction before reaching the edge. Just how close it seemed to go I cannot say, because of the contradictory experience just noted.

When the other observers were called all agreed for a short time in their general descriptions of the movement. All seemed to get the illusion very readily, though possibly not immediately. We tried to sight by the edges of trees a few feet away, but in this we had no success. As the edges could not be clearly seen against the dark background afforded by the mountain, the sighting had no tendency whatever to annul the movements of the light. It is, however, possible that the projection of the trees above the image of the mountain, where they could be clearly seen, had the effect

of preventing extensive side movements of the light. Some of the observers were speculating as to whether some one might not be moving the light from a point not far away by means of strings. The high school girl, whose roommate was away, was frightened, regarding the phenomenon as supernatural! Those of us who suspected that the movements were illusory soon got confirmation of their view. Contradictions soon began to arise as descriptions passed beyond mere exclamation to greater accuracy. "There it goes, shooting upward to the right," *A* would say, only to be contradicted by *B*, who would declare that it was at the time actually moving slowly, or, perhaps, that it was going downward. It became evident that no two were having the same illusions.

It was then decided by the writer to arrange apparatus for accurate sighting, so that we could see what effect this would have on the illusion both during the time of sighting and



afterwards,—after the *fact* of the illusion had been clearly established wholly within the experience of each observer. Accordingly a dark east room in the house was chosen for an observation point. The light, it will be recalled, was to our east. In this room a head-rest was constructed a little over a meter from the window. From behind the observer's position, through a small space over and by the side of the door to an illuminated room a triangular ray of light was admitted. This ray was reflected from the window into the observer's eye, as shown in the accompanying figure, so that it would be seen outside of the window (at T) in the form of a triangle about four meters from observer. The head-

rest was so adjusted that the light on the mountain was seen just above the point of the triangle. To any one of us as observer under these conditions the light on the mountain was seen to be absolutely stationary. Immediately, however, on removing his head from the head-rest and getting away from the controlled conditions of observation, the observer would again see the illusion as before. That is, the check of the experimental conditions had only a momentary effect on any observer: *the illusion persisted under normal conditions of observation even when it was understood, and had been shown by the observer's own experience, to be an illusion.* How much a considerable amount of practice in observation under the controlled conditions would in time affect the extent of the illusion was not determined. It is regrettable that under the rare conditions of the illusion at hand the effect of practice was not studied more fully. This may be done, however, in the laboratory. It has not yet been undertaken, I believe, though important studies have been published on the autokinetic illusion from the Chicago University laboratory since this illusion was perceived and partly written up.[2]

The light on the mountain was simply a camp fire by which some poor fellow was likely drying himself in the rain, wholly unconscious of the part he had played in our experiment. The writer has several times since the experience here described seen illusory movements of lights on mountains, but as, in very case, the lights were not so favorably located and the nights were not sufficiently dark, none of the illusions has been so marked. The movements as a rule have been but short, irregular fluctuations about the true point of the light, resembling more nearly the *Sternschwanken* of the early astronomers.

An illusion of the type here described, which was seen in the writer's childhood, is on the whole still clear in memory. Altogether three or four children and two adults witnessed the phenomenon, which was at the time wholly incomprehensible to the observers. It was regarded as something supernatural. A town about five miles from the one in which we were living at the time had just been, or was being, terribly ravaged by diphtheria. One family in two attacks of the disease had lost seven children, it was reported, leaving only the parents. The scourge had touched the more remote parts of our own town, taking a toll of three children from one

[2] Carr, H. A., "The Autokinetic Sensation," *Psych. Rev.*, XVII, 1910, 42. Adams, H. F., "Autokinetic Sensations," *Psych. Rev. Mon.*, No. 59, 1912.

family (including the writer's playmate) and one from another family. Stories were current of the dreadfulness of the disease and of how the dead were buried in the night. Beyond this town about seven miles was a mountain range possibly 800 meters in height, affording a favorable field for the illusion. This range, which our line of vision met at right angles, extended many miles both to the right and to the left. The illusion was witnessed on a dark night, and the observers watched it a long time with more interest than that of mere curiosity. It consisted of a large light moving horizontally from side to side over the unfortunate town. We considered it to be some sort of omen having relation to the scourge. Our descriptions, so far as memory serves me, were not specific enough to lead to obvious contradictions; and no one was in a mood to challenge any slight discrepancy. There was, however, some discussion as to whether the light did not have a short tail trailing behind it. I remember distinctly that its movements seemed to be more or less arbitrary, presenting occasional hesitancy and again sweeping at a nearly uniform rate for an apparent distance of one to two or three miles over the town. These long movements do not now seem to have taken more than a few seconds. They were not uniform in length and, it would seem, the light occasionally made actually less progress than the rate of movement would lead one to expect. The light moved only laterally, never up or down, as is now easily comprehensible since the dark field (the distant mountain) was narrow vertically and extended laterally.

Obviously this phenomenon was an autokinetic illusion. The light, which appeared very large even at the distance stated, was doubtless a fire on the mountain about twelve miles from the observers. Because of the state of mind of the persons witnessing the phenomenon, their interest in the neighboring town, the light was erroneously perceived to be the same distance away as the town. Normally in spatial perception our focus is on the object which receives the attention.

Of late, as has already been said, these illusions of movement of lights in dark fields, and of other objects presenting similar movements, have been subjected to careful study in the psychological laboratory. The phenomenon has been described as the autokinetic sensation, or autokinetic illusion. Various explanations of the illusion have been offered. One hypothesis has vaguely attributed the phenomenon to some unknown central factor—a very convenient way of disposing of the matter so long as no real explanation is at hand! Exner

has attributed the movements to overflows of the retinal excitation into portions of the retina near those stimulated. Three kinds of theories have been suggested which attribute the illusion to some sort of eye movements or tendencies to such movements, or to impulses commonly associated with eye movements. It is now well known that small, unconscious eye movements are constantly taking place. These small, quick movements, it has been suggested, may be fused unconsciously in such a manner as to give the impression ot a continuous movement of the light in any one direction, or the shifting retinal impressions due to such movements may fuse together with the same general result. But it is difficult to understand how these movements could become integrated to produce the different gross effects experienced.

The second eye-movement theory attributes the illusion to actual eye movements of a considerable extent. Carr has shown, however, that after-images developed previously to the illusion did not bear out this theory; also that the illusion takes place without such eye movements. Illusory movements to the extent of 60 degrees or more may take place with a constant fixation.

The third eye-movement theory—which is, however, in reality an eye-strain theory—holds that the illusion is due to some sort of strain or fatigue in some of the eye muscles, producing an effect of lack of balance which somehow affects one's consciousness or perception of the direction of the light. This theory seems now to be the promising one. I quote a paragraph from a recent supporter of this theory:

"When the eye is at any given position in the visual field, it is held there by the balanced action of the six extrinsic eye muscles. These muscles are not all of equal strength and some will become fatigued more quickly than the rest. When they are in this condition, it will take more of an effort, usually reflex in character, to hold the fixation constant; the fatigued muscle will be more strongly innervated. Consequently, more impulses, kinaesthetic and others, will be sent to the higher centers from that muscle. As these impulses have previously been associated with eye movements in a given direction, and since the fixation remains with the light, the subject will think that the light has moved in the direction in which the strain has been exerted. It produces the illusion of a pursuit movement. It is a matter of indifference whether the nerve impulses from the muscles arouse consciousness immediately or not, so long as they are capable of overflowing into other centers and thus produce the consciousness of movement. The movement must also be attributed to the light and not to the ideational space, for if it were attributed to the ideational space, the movement would be in the direction opposite to that of the strain, whereas actually is in the direction of the strain."[3]

[3] Adams, *op. cit.*, page 27.

Several experiments seem to support this theory and there are no serious objections to it. It is also obvious that some of the factors pointed out by other eye-movement theories may operate in some aspects of the autokinetic illusions, such, for instance, as are exhibited in the *Sternschwanken*. It must be remembered that perception is a very complex affair physiologically; that the visual perception of direction of any object cannot normally be isolated from that of all other objects in the visual field. When, therefore, the field is dark and presents only a single small light the visual checks by the various other objects are lacking and the illusion is apt to take place. It might be remarked that with only one such single experience there could be no direction sense at all, direction consciousness being—at least in its physiological aspects—wholly a relational affair. Even with the single light, direction must have meaning only in relation to certain marginal experiences or objects (tactual, kinesthetic, visual) and to certain bodily positions, which maintain for the time the general consciousness of the extension and location of the visual field in which the light seems to move. This is amply shown in illusions of direction orientation.[4] As a result of the formation of wrong visual associations during one's first experiences in a strange city or country, one may be "turned around" ever after in spite of efforts to correct the illusion. One may learn what the true north is and rationally orient one's self, but the *perception* still remains illusory.

It would be interesting to enquire into the frequency of the autokinetic illusion in the normal, or non-laboratory, experiences of man. The well-known *ignis fatuus*, popularly known as the *Will-o'-the-wisp* or the *Jack-a-lantern*, is likely due in large part, so far as its movements are concerned, to this illusion. It is a light that sometimes appears over marshy grounds, caused by the combustion of a gas formed by the decomposition of organic matter, the "marsh gas" or methane (CH_4). The conditions of the appearance of this phenomenon on dark nights (a small light in a large dark field) are entirely favorable for the illusion. It appears from reports of this "marsh light" that its movements are considerable. While some of the descriptions are undoubtedly exaggerated, it must be noted that a movement of 50 to 60 degrees, which under favorable conditions is entirely within the range of possibility, would seem to be extensive.

[4] Peterson, J., "Illusions of Direction Orientation," *Jour. Phil., Psychol. and Scientific Methods*, XIII, 1916, 225. Other references are there given.

THE BIOLOGICAL SIGNIFICANCE OF THE EYE APPENDAGES OF ORGANISMS

By P. F. Swindle

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I. Introduction

The following numbered statements include some of the more important observations which were made use of in formulating the system of thinking submitted in this article. Every outgrowth on the organism which is an obstruction to vision, will be considered an eye appendage; and any other object which serves the same purpose, will be considered a substitute for an eye appendage. For the sake of simplicity, only one or two kinds of animals are referred to in each case. It must always be borne in mind that some of the statements (1-14) are only very general ones; a number of exceptions can be noted in some cases, but a few of the statements scarcely need qualifying.

1) Nocturnal animals have as a rule white whiskers (cats).

2) Those of the diurnal animals are generally dark (squirrels).

3) Animals which are both nocturnal and diurnal have usually some white and some black whiskers; a single whisker may be for half its length black while the other half, the outer half, is white (rabbits).

4) Nocturnal animals which habitually nest in trees have some black and some white whiskers; the black ones project between the eyes and the sky, or the high objects in the trees, while the white whiskers lie between the eyes and the darker objects (in the night they are dark) the animal moves over (many opossums and raccoons).

5) Carnivorous animals possess, as a rule, the most pronounced whiskers.

6) While carnivorous animals lie in wait for prey they close the eyes seldom, but continually move the whiskers (cats owls, etc.).

7) Gregarious birds have usually no whiskers (partridges).

8) Whiskerless birds often nod the head quite periodically (doves, ducks, etc.).

9) Animals with oscelli and compound eyes usually possess prominent antennae which continually move before the eyes (the greater number of the invertebrates).

10) Those invertebrates which have the insect eyes and no prominent antennae, often raise and lower the body spasmodically or else move it from side to side (spiders).

11) As a rule creepers often thrust the tongue out of the mouth (snakes).

12) Many reptiles which lie quiet for long periods of time, often raise and lower the body or nod the head spasmodically (lizards).

13) Many aquatic animals which have no eye appendages frequently rock the body by lifting first one side and then the other (some salamanders such as Megalobatrachus maximus and Cryptobranchus alleghaniensis). Some cave forms have at most very degenerate eyes (Proteus anguinus).

14) Deep sea fishes often possess not only shaky telescoped appendicular eyes (Stylopthalmus paradoxus A. Br.), but some even carry luminous organs (they are supposed to be luminous) on pinnacles near the eyes (Melanocetes krechi A. Br.).

15) When a person carefully fixates with wide-open eyes a small object for only a few seconds, it subjectively disappears; but, as soon as the eyelashes are allowed to fall and for a very short interval of time obstruct the vision, the object reappears. Instead of dropping the lashes, one can cause the object to reappear by allowing a little smoke to pass between the object and the eyes. One can also move the eyes a few mm. to the side. Under any of these conditions the object reappears at once; but it does not necessarily retain its original color. If one carefully fixates a 10 x 10 cm. piece of green paper on a larger gray background, the color of the paper becomes induced on the background, and vice versa, to such an extent that all becomes one solid area of green; one can at times distinguish no transition from the paper to the background. However, if at this stage one lowers the eyelashes, the area of the colored paper becomes at once distinct, even though the color now observed is antagonistic to the previous

one. If one continues to thus move the eyelashes, or sprinkles dust particles over the paper, or spreads a tissue paper over it, or shifts the eyes a few mm. to the side occasionally, or closes the eyelids frequently while fixating, the form of the paper—whatever color it may from time to time assume—is easily retained.

16) If one fixates the green paper with half-closed eyes, it appears reddish after a very few seconds but retains its original form for a long period of time.

The function of eye appendages and their substitutes seems to be to retard the positive or self-induction and to hasten the negative induction of a color. An eye appendage or its substitute which serves this purpose, is a mechanism for training the visual apparatus to respond to colors in quite definite ways, as will be discussed in a later article. I wish now to do no more than merely mention that the organ of vision, including its appendages, is in truth a uniquely devised apparatus for training itself.

To hasten the negative induction of a given color, e. g. green, implies retarding its positive or self-induction, and from the biological standpoint this means of course no more than that a pause for green is hastily brought about. It is a matter of physiological necessity that a pause for green finally comes, simply because the nervous structures which are responsible for the sensation of greenishness cannot function indefinitely. After a recuperation pause for the structures involved, they can re-function and thus produce a second time the sensation of greenishness. If through some mechanical device the pause is hastily brought about, it need not be so long as it otherwise would be; green can be seen much earlier, and of course in a given time it can be seen much oftener. During the recuperation pause the organism is totally but only temporarily color blind for green. If an eye appendage brings about a pause for green before the exhaustion of the nervous structures for this color is very great, the organism will be able to respond sooner and in a given time oftener to the color presented it. The biological significance of this fact should be clear; it means that conditions are produced under which the organism is for no very great length of time blind to the particular color of the surface it fixates.

During the pause for green, I shall call it the 'green-pause,' the organism responds to a color which may be quite different from green; it is usually red, but it is of much greater biological significance that the area remains in one color or another than that it disappears entirely.

Each eyelash, each whisker, each condensed portion of a cloud of smoke, each dust particle, each translucent particle of a tissue paper etc., etc. serves as a background (or a foreground, if one should see fit to call it thus) however small it may be, on which a negative after-effect (in cases a positive after-effect) of the whole or a portion of a larger more distant object can fall either when the eyes move, when the background moves, or when the object behind the little background moves; each of these little backgrounds, whether it be an eye appendage or a substitute for one, produces a pause for a particular area of the retina that has neared exhaustion for green, e. g., but which can function strongly for the most unrelated color to green. Red appears as soon as this exhausted area for green (the exhaustion may be far from being complete) is no longer being directly stimulated by the green. When the nervous structures which terminate in the retina, become in a high degree exhausted for green, which occurs after many seconds of careful fixation, red will appear without the intervention of a background.

Any one of our little backgrounds serves exactly the same purpose for a limited portion of the retina as a large background does for the entire retina. The most natural background for the entire retina is the eyelid which occasionally falls, thus obstructing the vision entirely. If the small backgrounds are plentiful enough they also bring about a pause for the particular color of the fixated object, not necessarily for so many protected parts, but for the entire retina, i. e. for the unprotected areas as well; for the induced color, which makes its appearance under these conditions, can often not be said to be in any way different from that which appears when one closes the lids entirely. One great advantage in having numerous minute backgrounds instead of only one very large one is that the fixation can continue without the point of fixation shifting far or near or to the side; the organism is thereby enabled to see always the object it fixates, even though this object becomes subjectively differently colored.

II. Experiments, Observations, and Discussions

A. The Cat

But what would be the difference for a cat, provided the cat can discriminate between colors, if the mouse's nose it fixates should appear to the cat to be black, white, red, green, yellow or blue? A blue mouse would evidently be better than none. When a cat hears a noise in a pile of boards, it sits quietly near the boards and keeps its eyes turned in the direction of

the noise until the mouse makes its appearance, then the cat usually pounces onto it with one or both paws. If now a mouse comes to the end of a board and exposes only the nose, as mice generally do before scampering out into the open, the cat springs and captures the mouse by scraping it from behind the board with one paw which it can very expertly bend in a sharp angle to fit around the board. If the cat has no whiskers or eyelashes which it can continually move about in its field of vision as it fixates, it should theoretically be often unable to see the nose, because the nose, which is really a small point, should subjectively disappear. The cat must accordingly wait until the mouse shows a larger part of its body or comes entirely from behind the board and skips about. But mice very often show only the nose and turn back. The whiskerless cat would lose these opportunities, which are really good ones for a whiskered cat, and must necessarily live from the mice that venture into the open. Moreover, if a cat fixates an object before it begins to disappear and reappear, it cannot be blamed for growing restless as often as this occurs. And of course, if the cat moves about occasionally, this will disturb the mice. A smaller number of them would then leave their sheltered places to skip about the restless cat.

For many days I observed a cat while it was watching for mice. It evidently lived on mice and rats, for nobody fed it. During one afternoon I saw it catch two mice, and at dusk I found it with a rat. I deprived the cat of its whiskers and again observed it as it watched for mice. I saw it spring several times into the shucks and hay, but it captured no mouse while I was present.[1] It may of course be that I could not so well detect the presence of a mouse as even the whiskerless cat could, but it often seemed to me that the cat sprang when no mouse was about. I supposed that some of the objects which were in the cat's field of vision as it fixated, disappeared, and that when the animal moved its head or partly closed one or the other or both eyes, as it occasionally did, an object that had vanished suddenly reappeared and was mistaken for a mouse, perhaps not for the entire body but for such a small part as the nose.

The cat grew poor, each time it saw me it ran to me, rubbed for a while against my legs, and quite often looked me

[1] I saw it one day with a snow bird that had just been captured, and a few days later I saw it eating a gray squirrel. The squirrel, however, had apparently died from wounds from a shot gun, for I found a number of No. 6 shot in its body. It had been dead so long that its eyes had shrunk.

in the face and meowed. As a whiskered cat it never did this. Instead of feeding it, I glued some rabbit whiskers at various places on its face, as much as possible onto the old whisker stubs. These would move about somewhat as the original whiskers did. For the sake of economy, I tried to give the cat movable whiskers; for a single whisker that moves in the field of vision is certainly worth a number of stationary ones. As long as the false whiskers were intact, the cat behaved just as it originally did; I never observed it spring without catching a mouse. But every time the animal washed its face, the rabbit whiskers would be either badly displaced or scraped entirely away. Since this method caused so much trouble, I shot some horned owls and glued many long shaky pieces of feather down before and behind the cat's eyes. Especially when the ends of these were charged with electricity, which I generated on the cat's back and transferred to the ends of the feathers, they stood out on the face and waved back and forth, in a way resembling the movements of the round arms of a sea anemone. When the cat now washed its face, the down was usually left intact, and all I had to do was to occasionally straighten and recharge the pieces.

I convinced myself that when the cat had false whiskers, it was a much more efficient mouser than when it had none. I saw it catch more mice, and it seemed to get somewhat fatter; but it still remained hungry only for the simple reason that I could not all the while be with it to replace the down it lost, to straighten the pieces that became tangled with the hair, and to keep the ends charged.

I finally captured in a trap another very wild cat which remained in the woods and fields. I shingled its whiskers and eyelashes and set it free. For many days it roamed about as usual, but after about two weeks I often saw it lurking about an old house which had been deserted for more than a year. I never succeeded in getting near enough to the animal to judge whether it was as fat as usual. Through inquiries I learned that the cat belonged to the last family that occupied the house, and that when the animal was deserted it began to roam in the fields and woods. I suppose that it, as a whiskerless cat, became less efficient in catching its prey, finally grew hungry, and returned every now and then to the house where it was formerly well fed.

B. The Squirrel

The squirrel comes onto a branch and carefully fixates another onto which it is preparing to spring. Since the whis-

kers are prominent on the animal's face and since a number of these are directly between the eyes and the branch it fixates, this branch may become white, red, green, blue or any other color (assuming that the squirrel can discriminate between colors). But whatever color it may subjectively become, it still remains for the squirrel a branch to which the animal can respond by springing. If however the branch subjectively disappears, as should occasionally be the case with a whiskerless squirrel, the animal might spring and fall to the ground. With these ideas in mind I captured some squirrels, deprived them of their whiskers, and occasionally set one free. I watched these carefully as they went running and springing through the trees. Very often a squirrel would be in the attitude of springing from the end of a limb of one tree to one of a neighboring tree and after all not spring, but start down the branch it was on, then run back up this branch, fixate the branch of the other tree for a short time, again run down the branch it was on, return again, etc., before it would finally spring. I was quite unable to observe this sort of behavior, which I observed in a limited number of cases, in any marked degree when I chased whiskered squirrels through the woods, or when I remained quiet and observed large colonies of wild squirrels often for four or five hours at a time.

Every one who has given particular attention to squirrels, knows how they jerk the bushy tail when they walk slowly or come to a stand-still. Since this moving tail falls in the animal's field of vision, I thought the hairs on it might possibly play an analogous rôle to that ordinarily played by the whiskers. I therefore sheared the tail of an already whiskerless squirrel and set the animal free. The number of fixations before springing was now unmistakably more, and once the squirrel missed its aim and fell about five feet to some lower branches; later it once fell to the ground.

It can of course be said that the purpose of the squirrel's tail is to guide the body as the animal springs. I have no doubt that this is the case; we might therein find an explanation for the fact that the tailless squirrel missed its branch and fell, but there are in this connection some very important facts to consider.

Following are a few auxiliary observations made on the human being. If one fixates a piece of green paper, e. g., for a very few seconds, and then drops the lashes for a very short distance, however not so far across the field of vision that they come between any part of the paper and the pupil, not only the top part but the whole of it changes immediately to red. So it

seems that since lashes or whiskers that move in any part of the field of vision during the period of fixation, cause the fixated object to remain more distinct, the hairs of a squirrel's tail, which move also in the field of vision, even though behind or above the fixating eyes, would play fundamentally the same rôle. Those hair-like processes, however, which lie directly between the pupil and the object of fixation, whether these be the whisker-like feathers on the sides of an owl's beak, whiskers on the nose of a cat, or lashes on the lids of the human eye, are the more efficient in serving the very important biological purpose of avoiding a subjective disappearance of the object fixated. Even the eyebrows of many human beings (especially among the American Indians) and those of such animals as the eagle, even though these processes come to lie, under conditions, only in the upper region of the field of vision, serve the same purpose. When the eagle or the Indian frowns, as is especially the case when a distant object is being carefully observed, the eyebrows fall and project a short distance into the field of vision just over the eyes; and careful observation shows that they are usually in a perfect tremor. I can observe this best on myself. (I am not a full breed Cherokee, but I nevertheless have many characteristics of this tribe). When I observe a distant object, I involuntarily frown; then the eyebrows nearest my nose project over and before my eyes and quiver. Moreover the skin, which ordinarily lies over the prominent bone projections above and toward the outer corner of each eye, falls at the same time against the eyelashes, thus shoving them over the pupil, though not entirely over it, but usually over only the upper part. Since this skin quivers rapidly, the eyelashes, which it is pushing down, also quiver. The eye of the Indian or of the eagle is, I think, a uniquely efficient apparatus for observing objects at great distances.

It does not matter whether the organism remains quiet as it fixates or whether it moves steadily about from place to place; it may soar in the air or walk steadily over a surface and still lose an object it fixates. When the surface is more or less homogeneous, such as is the case when a snow is on the ground, the fixated objects disappear more readily. While I was in the Ozarks, during the months of November, December, 1915, and the greater part of January 1916, hunting and performing the experiments already mentioned in this paper, I often found it necessary to walk a few miles to my hunting grounds. I followed the railroad track and learned to walk a rail for the entire distance without falling. Often after I had walked a mile or two, the track subjectively dis-

appeared, but returned again as soon as I puffed some smoke, not necessarily between the track and my eyes, but merely formed a smoke cloud at some place in the field of vision, or frowned, or reached my hand out before my eyes merely so that I could view it peripherally, or merely glanced at some distant object. At other times the track did not entirely disappear; when this was the case the parts between the ties remained quite normal while the other parts seemed to dip and pass under each tie. It was necessary for me to walk very steadily and at the same time fixate the track. My fixating the track as I walked steadily over it was analogous to my standing still and fixating a limited portion of it; under this condition it also disappeared for me. This was especially true at dusk, for the track, which was then for me much more like its surroundings, disappeared much more readily than in the day time.

When the rail apparently dipped under the ties, each tie was of course subjectively continuous where it was previously cut by the darker rail; each tie that crossed my field of vision induced itself across the darker rail. I observed in each case no more than an induced positive color (I use the Ladd-Franklin terminology and call everything colors excepting the psychological absolute black which I will define in a later article) of the tie and indeed an effect of long duration; for when I stood still I could often observe the induced color for a minute or more, i. e. until the entire tie disappeared, or, until I made a sudden movement of any kind, lowered the eyelashes, frowned, or did anything else of similar nature. In connection with this, I found it interesting to stand on the small railroad bridges (where the ties are much closer together than ordinarily) and fixate a tie and observe it as it suddenly flowed, as it were, to the neighboring ties, which in turn seemed to flow into the next ones, etc., until all became one homogeneous surface. I could easily avoid this illusion by throwing, among other things, the lashes over my eyes. It certainly did me no harm to have this illusion. If I had taken a step forward to walk to the other end of the bridge, the chances are that I would have stepped on a tie, for the simple reason that they were only about six inches apart: however, if my feet had been quite small I could possibly have stepped between two ties. If I had taken a step to walk to the other side of the bridge, i. e. across to the other rail, the chances for my falling would have been greater.

I can avoid the simultaneous positive induction of the color of the ties very easily by moving my hand in my field of peri-

pheral vision; I need not bring the hand between my eyes and the ties. It would seem that it is just as unnecessary for the squirrel's tail to fall directly between the animal's eyes and the branch it fixates. The jerking tail serves a distinct biological purpose even though it never falls directly between the eyes and the objects before the squirrel. We must furthermore consider that the squirrel often sits on its haunches and brings the tail up over its back. When it sits thus the tail is more directly in the field of vision, and this should really be the case; for the eyes are now in such a position that the squirrel can observe objects back of it almost as well as before it.

C The Rabbit

The rabbit certainly needs no whiskers while running, for it does not move steadily over the earth, but leaps and bounds. Since the animal lies roughly entrenched, in a high degree unsheltered, during the day in open fields and with its head motionless and close to the ground. it needs black whiskers which project between the eyes and the sky, or in other words between the eyes and its diurnal enemies. Such whiskers are really present and they are constantly moving. The rabbit, which is by nature nocturnally inclined, is compelled by its many diurnal enemies to be more or less passively diurnal itself.

The rabbit would need no whiskers in the night time provided it never stopped running, but since it does stop and moreover since it often sits on its haunches, it really does need some. Furthermore, since it runs in the *evening* and at *night*, it needs some *white* ones. A white whisker on a dark background is of course more effective than a black whisker would be. When the animal is in the sitting posture, its head is quite differently inclined than while it is running or lying. The nose is now considerably higher than the eyes and consequently, owing to this position of the head, the white ends of some long half black and half white whiskers, which are rooted so low down under the nose that they serve the animal no purpose as it lies in its bed, now fall between the eyes and the dark objects on the earth. It is also interesting that the outer or white ends of these whiskers fall between the eyes and the more distant objects while the inner or black ends obstruct the vision for the closer ones. The black diurnal whiskers are thus converted into nocturnal ones by being thrown between the eyes and the horizon; and the white or nocturnal ones, which were of no use to the animal during the day, now lie in the most favorable possible position. This arrangement of the whiskers

of the sitting fixating rabbit enables it, among other things, to observe carefully its many nocturnal enemies. Besides its whiskers, its long moving ears also play a prominent rôle as eye appendages; the ears would seem to render a long bushy rabbit tail a nuisance as an eye appendage.

D. The Opossum

The opossum sleeps soundly during the day in secluded places, usually in tree cavities or in deserted nests of other arboreal animals. In the night time the animal walks or trots *steadily* over the earth. It should therefore have two sets of whiskers, some white ones which fall between the eyes and the dark objects it moves over, and some black ones which lie between the eyes and the higher objects which are surrounded by the light sky.

III. Conclusion

Paradoxical as it may sound, it seems that appendages on the body and substitutes for these which are really physical obstructions in vision, may after all have the very important biological significance of enabling the organism to retain objects it fixates. Since the carnivorous animals must necessarily fixate very often and for exceptionally long periods of time, it is not strange that they possess the most elaborate eye appendages. The herbivorous animals do not need to fixate so carefully the herbs they live on, but the significance of the occasionally highly developed eye appendages is nevertheless often to be understood when one carefully studies the activities of these animals. It is moreover not strange that animals which possess neither a great number of these appendages nor even a few moving ones, should very often spasmodically move the head or the entire body. Animals which live in flocks have a sufficient number of substitutes for eye appendages at their disposal. For any one of these animals, other members of the flock play the part of moving eye appendages. This is only one example of innumerable substitutes for eye appendages.

PRELIMINARY NOTE: THE INFLUENCE OF CHANGES OF ILLUMINATION UPON AFTER-IMAGES

By Leonard Thompson Troland, Harvard University

The conditions under which the quality and duration of after-images can be studied are so extremely varied that generalizations concerning the after-image process have little value in the absence of a detailed control and specification of these conditions. For this reason, I undertook, several years ago, the investigation of after-images produced under very special, but carefully controlled conditions, in the hope of obtaining consistent results. At an early stage in the research, I found that such results could only be secured when the effective aperture of the pupil was kept constant, because the character and life of an after-image depends not only on the momentary nature of the retinal stimulus, but upon the variations which this stimulus undergoes.

In all of the measurements to be considered in this paper, an artificial pupil, 2.36 mm. in diameter, and registered with respect to the line of sight by a device which I have described in another place, was employed. The after-image was produced by preëxposure of the rested retina of one eye to a semi-circular field, fixation being directed to a point in the center of the diametric boundary. The after-image was always observed by projection upon a complete circular field of the same quality as the semi-circular stimulus, fixation being maintained on the center of the circle, so that the conditions of observation were similar, in general, to those presented by a simple bipartite photometer field. In all cases, the surroundings of the test area were objectively dark, and the wave-length constitution and photometric brightness of the stimuli were carefully determined in absolute units.

Under these conditions, the mean variation of the time of decay of an after-image, for a single trained subject, is about 8%. It is not my intention to discuss here in detail the results of numerous measurements of the duration and intensity of after-images of this sort, made with a wide range of wave-lengths, and stationary intensities. It will suffice to say that

the duration is nearly independent of wave-length, and of absolute intensity, but varies radically with the diameter of the field and with the individual, as well as with the preëxposure time. Decrease of the stationary intensity below 10 photons (10 candles per square meter with a one square millimeter pupil) lowers the duration, and there is also a slight tendency for it to be lower in the red end of the spectrum than in the blue end. Increase of the preëxposure time above 100 seconds causes practically no increase in the duration. For myself, using a 1¼° foveal field, the maximal duration[1] varies from 70 seconds in the red to 95 in the violet.

In view of the slight influence of the magnitude of the fixed intensity, the remarkable effects produced by intensity variations in the reacting field, are of great interest. These effects may naturally be classified into two groups, those due to dimming and those due to brightening of the field. Hering and his pupils have made considerable use of dimming phenomena in their experiments to support the theory of antagonistic colors.[2] The recent very interesting studies of G. H. Miles—published since my results were obtained—on "The Formation of Projected Visual Images by Intermittent Retinal Stimulation"[3] undoubtedly bear upon the same fundamental processes.

If an after-image, formed and projected in the manner already described, be permitted to fade, and if then, the after-image of the projection field itself be observed against a completely dark ground, a demarcation of the field into halves can generally be noted. This effect is always obtained with short preëxposures and high intensities, but is absent for preëxposures which approach in duration the "equilibrium time," or maximal duration of the image.

If the intensity of the projection field is decreased, but not made zero, a similar but usually far more striking rejuvenation of the after-image contrast, occurs. The preëxposed half appears darker and more or less complementary in hue as compared with the other half of the field. In its general form, the principle that *dimming the reaction light enhances the processes which are "antagonistic" to the original stimulation,*

[1] The duration increases asymptotically with increase in the preëxposure time. For a discussion of this law, see L. T. Troland, Apparent Brightness; Its Conditions and Properties. *Transactions of the Illuminating Engineering Society*, XI, 1916, 947-967.

[2] See *e. g.*, R. Dittler, and Satake, Eine Methode zur Bestimmung der gegenfarbig wirkenden Wellenlangen des Spektrums. *Zeitschrift für Sinnesphysiologie*, XLVIII., 1914, 240-252.

[3] British Journal of Psychology, VII., 1915, 420-434.

is familiar to all readers of Hering. However, in order to account for the increase of the after-image contrast, the principle must have a special mathematical form, since if dimming affected both halves of the field equally, the contrast would not be augmented, however great the absolute alteration of the compared areas. Consequently, it is necessary to state that a very slight difference in the level of fatigue of two visual areas furnishes the condition for a large difference in the magnitude of the *dimming effect* producible on these two respective areas. This is the principle of the *dimming contrast effect*.

An explanation of this somewhat extraordinary principle is suggested by further study of the phenomenon itself. The contrast, which has been reëstablished by dimming, fades quite rapidly on the dimmed field, but if—after it has disappeared—the field is brightened to its original intensity and then dimmed once more, the contrast returns; a process which can be repeated successfully over a period sometimes twelvefold the life of the image on the undimmed field. This factor of the relative *durability*[4] of the dimming contrast effect decreases rapidly to an asymptote with increase in the original preëxposure time; in other words, the effect is less marked in conjunction with a generally low level of visual sensitivity than it is with higher levels. Increase in the degree of dimming reveals a maximum of the "durability" of the effect in the neighborhood of one-half the primary intensity. From $100\,\sigma$ to $600\,\sigma$ the durability increases practically as a linear function of the time during which the dimmed intensity is maintained at each successive test. Between .7° and 3.5°, a linear relationship exists between the durability and the diameter of the stimulus field. When the primary intensity is varied, and the dimming is always to a constant fraction of this intensity, the effect shows a maximum in the neighborhood of 100 photons, depending on the value of the fraction. This law also applies to the maximal duration of the dimming contrast in the dimmed phase, if this is prolonged. The latter duration decreases asymptotically to zero in successive intermittent dimmings.

Certain of the above facts strongly suggest that the dimming contrast effect depends upon a difference in the rate of decay

[4] The "durability" is to be distinguished from the "duration" of the effect, the former term referring to the period during which it can be obtained by repeating the process of dimming (and brightening), the latter designating the life of the image in a single cycle of illumination change.

of some component of the excitation in the contrasted fields, this decay taking place more rapidly in the more fatigued area. In other words, the more fatigued area shows a lessened resistance to change in its state of excitation. The dimming contrast, on this theory, should be in evidence only *during* the change, and the fading of the contrast would indicate that the change had been completed in both halves of the field. On the other hand, if the change were repeated, by brightening and redimming the field, the contrast would reappear, but would persist a shorter time than before, because of the nearer approach of the resistance factors of the two halves, to equality. This explanation applies to both the chromatic and the achromatic aspects of the phenomenon.

The assumption that exposure of a visual area to stimulation decreases the resistance which it offers to change in its state of excitation is in harmony with the laws stated by Helmholtz for the duration of positive after-images,[5] and is also borne out by the remarkable effects produced by *brightening* of the field under the general experimental conditions above described.

When the field is brightened, in general the faded negative contrast is *reversed,* and becomes *positive.*. The preëxposed half appears brighter than the non-preëxposed half, and becomes more saturated than the latter, which tends to acquire a hue complementary to it. This *reversal effect,* or brightening contrast effect can be obtained either by brightening on the basis of the primary stimulus intensity, or by dimming, permitting the dimming contrast to fade, and then restoring the primary intensity. The positive contrast fades rapidly on the brightened field, but—as in the case of the dimming contrast—can be rejuvenated by repeating the cycle of operations. With a spectral red stimulus, the total durability of the reversal effect, seems to be of the same general magnitude as that of the dimming contrast effect, when the field is alternately dimmed and brightened with equal intervals. To obtain the reversal contrast at its maximum, it is necessary to permit the preceding dimming contrast to fade completely, and *vice versa.*

I have made a number of careful studies on the laws governing the duration of the reversal contrast after any single brightening, when the bright phase is prolonged. In these experiments, the reversal was obtained by first dimming the primary intensity and then brightening it again, after an interval. It was found that the duration of the contrast increased to a maximum as this interval was lengthened, and then

[5] Handbuch der physiologischen Optik, 3te Auflage, 2, 1911, 194-202.

decreased asymptotically to zero. A similar law was found to connect the duration with the dimmed intensity, a maximum occurring for a dimming to about 1/50th of the original value. Variation of the preëxposure time also produces a maximum, and an asymptotic fall with the higher preëxposures (under the conditions which I employed, above 20 seconds). Other things equal, the effect is much more marked on large than on small fields.

These correlations are consistent with the view that the reversal of the negative after-image caused by brightening of the projection field, also depends upon a lessened resistance to change in state of excitation, due to preëxposure. The reversal, like the dimming contrast, persists only during this change, but can be rejuvenated by repeating the cycle of operations. In other words, the two phenomena are obverse and reverse of the same underlying condition. I do not claim that there are no difficulties to be met by this view, but it offers the most satisfactory synthesis of the facts that I have yet been able to find.

One difficulty lies in the manner in which the two effects vary with the wave-length of the stimulus. I have thus far not made searching experiments on the influence of wave-length upon the dimming effect, but cursory observations with representative spectral colors have not shown any marked influence of this factor. The dependency of the reversal phenomenon upon wave-length, however, appears to be quite clear cut. When the intensity change employed has a 10:1 ratio, the reversal is obtained at very low intensities in the red end of the spectrum,[6] but as the stimulus moves towards the blue end, higher and higher primary intensities are required, and the effect is absent beyond the green under all conditions which I have tested systematically.

The colors and color contrasts generated in the dimming effect are extremely vivid and variegated. In general, as would be expected, dimming tends to move the apparent color of the field along the spectrum towards the complementary of the "real" color. The spectral distance moved through increases with increase in the fractional dimming, with increase in preëxposure, and with decrease in the primary intensity. The direction of movement[7] in the spectrum, as well as the distance, varies with the wave-length of the stimulus. From

[6] These experiments were carried out at the Nela Research Laboratory.

[7] Direction of movement is determined by use of a graded series of values of the governing variables.

the extreme red to the yellow the change occurs through the purples; between the yellow and yellow-green there is reversal of the direction; between green and blue-green a further reversal; between blue and violet a third change; and between violet and extreme red, again, a fourth shift in direction. These facts indicate that there are four points in the color circle, for which dimming would produce only a saturation change, unless it could suffice to produce the complementary. In all cases the color contrast fades far more rapidly than does the luminosity contrast. It will be observed that all of these relations are in harmony with Hering's general schema of the visual qualities.

Although certain aspects of the dimming and reversal phenomena are explained by Hering's assumptions, these assumptions are by no means sufficient. Moreover, general physiological objections to Hering's doctrine of sensory metabolism make it illegitimate to employ his hypotheses in the exact form in which he stated them. However, my attempt to modify his views[8] so as to meet these objections yields postulates still less adequate, so far as the dimming and reversal effects are concerned, although they satisfy the laws for fatigue with stationary illumination much better than do Hering's original conceptions. My present opinion is that the former effects depend either upon the laws governing certain of the "constants" or parameters of the simple equations for retinal excitation, or else that they rest upon conditions in the visual system posterior to the retina.

I have met with some success in an attempt to explain them as a result of *Bahnung*, or the reduction of synaptic resistance by excitation. On this basis, the rate of change of excitation in a synapse may be conceived to be proportional to a force factor, representing the intensity of the incoming current, and inversely proportional to a resistance factor, representing the susceptibility of the synapse to alteration of its state. This makes the excitation an exponential function of the time after any change in the force factor, and of the resistance. The resulting equations meet many aspects of the experimental situation in a satisfactory qualitative way. However, at present, I regard this theory as highly speculative.

In connection with the above, I wish to mention several phenomena upon which thus far, I have made no detailed quantitative studies. In the first place, by use of the dimming procedure, after-image contrasts can be obtained which endure

[8] L. T. Troland, Adaptation and the Chemical Theory of Sensory Response. *American Journal of Psychology*, XXV., 1915, 500-527.

three or four minutes, on the basis of only an eighth of a second difference of exposure of the two halves of the field. I have been unable to secure these contrasts with red light, but they are easily produced with blue. Under these conditions, positive contrasts, or reversals, are sometimes obtained during the dim phase. Another interesting effect is the spontaneous appearance of a reversal, immediately following the disappearance of an ordinary negative contrast (through fading), without alteration in the intensity of the field. This effect is obtainable with all of the spectral colors, but most easily with the end-regions of the spectrum, and with short preëxposures. It is also possible to produce a positive image as an initial result of preëxposure, when the blue end of the spectrum (especially the blue-green) is employed and the preëxposures are less than 16 seconds.

VALUE *VS.* TRUTH AS THE CRITERION IN THE TEACHING OF COLLEGE PHILOSOPHY

By Wesley Raymond Wells, Washington University

The teacher of philosophy tends to be so exclusively a system-builder, with an eye single to the logical construction of his philosophy, that the concrete, human needs of his students are apt to be lost sight of. In general educational theory there is taking place a reform of method, and a reaction against the mere teaching of subject-matter regardless of the interests, aptitudes, and needs of the pupils. Teachers formerly taught subjects of study; now they teach children. The lesson learned from the elementary schools, that teaching should be ordered to fit the psychological needs of the pupils rather than the logical claims of the subject-matter, may with profit be extended to the teaching of philosophy to college undergraduates.

The vast majority of individuals never become students of metaphysics in any technical sense of the term. Of those who study philosophy in college, many simply "take courses", for sundry reasons, without ever acquiring much interest in the subject. With a large number of the students who really become interested in philosophy, religious doubt is the beginning of a philosophical interest that arises in the attempt to bolster up a waning faith. Metaphysical interests arise in others as a direct outgrowth of the developing sex life in early adolescence, as in the case of Don Juan, who—

> "Did the best he could
> With things not very subject to control,
> And turned, without perceiving his condition,
> Like Coleridge, into a metaphysician.
>
> "He thought about himself, and the whole earth,
> Of man the wonderful, and of the stars,
> And how the deuce they ever could have birth."[1]

As the poet says, with true Freudian insight, "puberty assisted" in bringing about Don Juan's philosophical interests.

Mere intellectual curiosity, or the pure love of wisdom for its own sake, is a possible though negligible cause of a

[1] Byron: "Don Juan," xci, xcii.

student's interest in philosophy, at least at the beginning of his studies. As a general rule, philosophy is valued at first only as an aid in solving the fundamental problems of life, and not as an end in itself. With prolonged study, perhaps unfortunately, philosophy may become an end in itself, divorced from all practical problems of life, through a psychological process like that involved in the case of the man who took his first drink to save his life, and thereafter lived to drink.

"Longings sublime and aspirations high" come naturally enough during adolescence, and the instruction of college undergraduates should have due regard to the moral needs of the students. College students of philosophy desire little philosophic dogmatizing from instructors, but, on the contrary, a free field in which to draw their own conclusions. The trend of their speculations can be guided, however, if instruction is insinuated gently, and not applied bluntly. Since metaphysics is a subject on which the most learned of doctors disagree violently, disciples are free, to a large extent, to choose metaphysical conclusions,—such, at least, as are really relevant to human concerns, upon the basis of value, regardless of truth. The question thus presents itself as to the sort of philosophic beliefs that are most valuable for students. This problem is similar to the problem of the value of religious beliefs.

Whatever may be the latest philosophic conclusions of a teacher of metaphysics, they are usually not the same as his earliest conclusions. The failure of a man's metaphysical views to broaden and grow with continued study would be an indication of intellectual stagnation. In every special science, at least some few results are established, and accepted by all scientists without question. Such results have become fixed in the elementary text-books. But metaphysics is a different matter. There is no generally accepted text-book of metaphysics. When it is the case that the teacher of philosophy has come to have somewhat different philosophic views from the ones that he held when he was a younger student, as is the normal case, he is very likely to infer from this, if his attention is called to the matter, that his own students will not at first acquire philosophic truths in final form. Even if there be final and absolute Truth in metaphysics, the human acquisition of this Truth is a psychological process, always incomplete and always imperfect. The teacher of philosophy, as a teacher, should be primarily concerned, not with absolute Truth, its existence being granted for the sake of argument, but with the psychological learning processes of his students in

their acceptance of some views and rejection of others, for emotional as well as for logical reasons. The student believes that his conclusions are reached by purely intellectual processes, but the educational psychologist recognizes that the passional nature is a large factor in the process.

Since human nature is such as it is, idealistic systems of philosophy, whether true or not, will always appeal to students of philosophy, and will be accepted by many for the reason that man's emotional nature, in so many cases, requires some sort of idealistic beliefs about reality. As James says, man's "will to believe" will assert itself in a large percentage of cases, and will accept an idealistic view of things because such a view is congruent with certain vital needs. Whether or not many of the current systems of philosophy that are called idealistic really offer support to man's specific religious beliefs,—even the most general and fundamental of them, is a question that need not be raised. They at least *seem* to most students to do so,—to offer a refuge of respectable supernaturalism against the encroachments of scientific naturalism. Upon the basis of value, and regardless of objective truth, the teaching of the great historical systems of idealism is certainly justifiable.[2] To force upon students a completely naturalistic philosophy, even if such were the true philosophy, —a philosophy that proclaims the universe to be essentially indifferent to the ideals of man, would be extremely disintegrating, especially for those adolescents who were glowing with the enthusiasm of new moral aspirations. Naturalistic beliefs would crush out the incentive to noble effort. But belief in idealistic philosophies, with their appearance of devoutness, however vague, lends grandeur to the universe, and zest to the moral urgings of the individual life. Several students of my acquaintance, now graduate students in philosophy and in other departments at Harvard, have told me that, while not now calling themselves metaphysical idealists, they nevertheless gained moral support and stability of character through studying, when undergraduates, such sympathetic treatments of idealism in its modern historical forms as are found in some of the chapters of Royce's Spirit of Modern Philosophy. This is, I think, a not uncommon experience. It is reported[3] that Jowett encouraged the study of the philosophy of T. H. Green by Balliol undergraduates because of its religious value for the students who were in search of a substitute for their earlier religious beliefs.

[2] *Cf.* G. Stanley Hall: Adolescence, vol. ii, p. 551.
Cf. F. C. S. Schiller: Studies in Humanism, pp. 278, 79.

Moral idealism is *theoretically* independent of any particular religion or system of metaphysics. It can be established to the full satisfaction of the intellect along with a naturalistic metaphysic as well as with an idealistic one. But *practically,* for actual human beings, most of whom, fortunately, are very incompletely intellectualized and de-emotionalized, theoretical moral idealism can become embodied in actual conduct only through the instrumentality of religious and idealistic beliefs. Belief in God and immortality, for example, tends to moralize the whole life, and to support such forms of conduct as are judged by the theorist to be right. The ethical theorist is concerned with discovering *what is right.* The preacher is concerned with influencing the will of man *to do the right,* that is, with making man's conduct conform to the standards set up by the theorist. Similarly the teacher of philosophy has a mission to perform in offering to youthful students such philosophic beliefs as will encourage, not discourage, moral effort on their part.

The educational psychologist would prescribe the early studies in philosophy upon the basis of their psychological adequacy, and their emotional congruity with the requirements of the moral life. A sympathetic presentation of the idealistic philosophies of history, with a greater effort at exposition than at criticism, has valuable results, while the exclusive teaching of naturalistic views would have disastrous moral effects. Perfect intellectual honesty and candor on the part of the instructor can be united with a due regard for the values of the metaphysical views that are incorporated in the various idealistic philosophies in history.

THE TERM REACTION TIME REDEFINED

By P. F. Swindle

For a particular simple or complex reaction, the cockatoo has at least as many reaction times as it is trained to have. By the term reaction time should be understood *the time which intervenes between the presentation of a stimulus and a response in which we are interested.* The natural reaction time to the stimulus green is too short for our modern instruments to measure; this is certainly the case with human beings, and we have no reason for assuming that it is any different with a bird. The most primary reaction to green is the immediate response to green, and not a certain movement we may be particularly interested in that succeeds the activity which is responsible for the psychical state of greenishness. We may say that the organism 'explodes' to green; we perhaps know of nothing more sudden than this explosive response. If we wish to demonstrate the existence of a different reaction time for the green-response, we may choose another stimulus—such as red; after the organism is stimulated for some time by red, it responds as if it were stimulated at this late period by green rays. This occurs while the eyes are open, and in spite of the fact that the stimulus red is all the time present. We may assume that, as is the case with human beings, the red grows less and less saturated and finally gives way to green. If the cockatoo is inclosed in darkness for a very short time after it has been stimulated for a few seconds by red, it responds in this case also as if to a green stimulus. Moreover, if it happens to close its eyes after it has been stimulated for a few seconds by red, it responds as if to green.

The cockatoo was trained to beat a particular group of movements, a unitary group[1] containing five elements, which was beaten in a particular tempo, (0.40 sec.) amplitude, and direction of movement when suddenly stimulated by flashing a searchlight through green glass. I shall call this a 5-group (5-g). The bird did not beat the 5-g when the light was flashed on it through a red glass; it was not trained to beat

[1]For information concerning the "unitary group of movements," see my experiments "Ueber einfache Bewegungsinstinkte und deren künstliche Beeinflussung." Zeitschrift für Sinnesphysiologie, Bd. 40, 1915

the 5-g as a conclusion to the immediate response produced by the red flash. Nevertheless, when it was illuminated for about ten seconds through the red glass and then the light was extinguished, making the room considerably darker thereby, the 5-g was regularly beaten. It evidently beat the 5-g after the green appeared as an after-response to the stimulus red.

It was accidentally observed that when the cockatoo was placed near an electric light and left unmolested until it became very quiet and closed the eyes for a period of many seconds, it almost invariably beat the 5-g very shortly after the eyes were opened. This response occurred whether the light was removed or not. I assumed that as long as the eyelids were closed, the cockatoo responded to the blood red of the illuminated blood-saturated eyelid, and that when the bird opened the eyes—thereby removing the stimulus red—it responded as if to green, i.e., the green occurred as an indirect response to the stimulus red. The responses occurred according to the following serial order: red-response, green-response, 5-g. The reaction time of the 5-g was determined by the time required for certain red- and green-responses to occur. This time was considerably shorter when only the stimulus green was used. This is in truth, such a remarkable series of responses that we must concern ourselves further with it. In the first place *we must ask ourselves what the essential differences between the red-, the green-, and the 5-responses are.* We will often find it valuable to use the term *group* instead of *response.* Our series would then read, red-group, green-group, 5-group. We must furthermore ask ourselves the question, *why it is that green-groups follow red-groups, and vice versa.* We know that the bird was trained to conclude the green-response with the 5-response or 5-group. *Is it not then logical to assume that red-groups are concluded soon by green-groups and vice versa because the animal has been trained to respond thus?*

Before going further, we may profitably discuss the training method which can serve to bring about such an alternation of responses as that of the red- and green-groups, and demonstrate its efficiency in any and every field of behavior. While this will be essentially a discussion of a training method, we will find ourselves continually concerned with the problem of reaction time.

The particular training method we shall now discuss is applicable to every field of activity, however simple or complex the responses in question may be, and regardless of the complexity of the subject to be trained. A few illustrations with

which every one of us is acquainted are as follows: a person smokes a cigarette and thus stimulates himself with the unusual stimulus tobacco smoke. The complicated response thus produced I shall call simply the tobacco-response. The person does not continue smoking the first time, but as to why he does not smoke one cigarette after another in rapid succession, I will not take time to discuss here. He makes a pause for the tobacco-activity, and during this pause other activities occur and become associated with the tobacco-response so that later, when the tobacco-response occurs, the second activity follows it. Whenever any two activities occur simultaneously or in a juxtaposed order, they thereafter occur more frequently in the same order. It is necessary that the adequate stimulus for oaly one of these activities act upon the organism, in order for both of them to occur. *The activity which is produced directly by the stimulus is an instinct; the indirectly produced one is a habit. The reaction times of instincts approach the zero value. An instinct is a response which follows immediately upon the presentation of its most adequate stimulus—and no other activity intervenes. A habit is a response which has at least one reaction time that is determined by the number and tempo of the elements of the one or more activities which intervene between the presentation of the stimulus used and the occurrence of the habitual response in which we are interested.*

When the first cigarette is smoked, at least two habits become established. The activity which by mere chance concludes the tobacco-response occurs hereafter more frequently than originally because it is now produced, not only as an instinctive response, that is, not only directly by its most adequate stimulus, but also indirectly by the stimulus tobacco-smoke. Likewise, the tobacco-response is now, not only an instinct, it is produced not only directly by the stimulus tobacco smoke, but also indirectly by the adequate stimulus for that activity—whatever this may happen to be—which terminates just as the tobacco-response begins. Later, whenever this stimulus occurs it produces directly its instinctive response which is concluded with the tobacco-response even though no tobacco smoke is present. This means that the person later responds more frequently than originally as if to tobacco smoke. He responds habitually to tobacco smoke.

If the person makes no pause for the tobacco-response the first time he smokes, this response will be in a high degree forgotten. The organic structures which the tobacco smoke excites to function can not function indefinitely. A pause inevitably comes, and if the stimulus remains always present,

not only while the activity is being carried out, but also during the recuperation pause for the structures in question, the stimulus becomes ineffective. I shall assume that it becomes ineffective because the structures which it ordinarily affects become highly exhausted, even though only temporarily. If a pause is produced artificially by removing the stimulus before the structures become in any great degree exhausted, the recuperation pause for the structures need not be very long. One essential condition that a person must fulfill in order to acquire the tobacco habit, is that he makes an adequate recuperation pause (for the structures the tobacco excites to action) before these structures become in a high degree exhausted. Another condition is that he applies the stimulus tobacco smoke each time he responds as if to this stimulus in its absence, otherwise there will occur that phenomenon of forgetting in time—or in other words, he will in the course of time become more active in other ways.

The same is true with the activity produced by fire which I shall call the fire-activity, or the fire-response. The person is active in a given way, at the conclusion of which he burns his finger with a flame. The complicated fire-response occurs and a pause is brought about for it by plunging the finger in water. Afterwards the person fears the fire, or in other words responds as if to fire when only the adequate stimulus for the preceding activity is presented. It is no longer necessary for him to place his finger in the flame in order to fear the fire; the fire-response is brought about, not only when its most adequate stimulus acts, but also sooner or later, whenever the adequate stimulus for an entirely different activity is presented to the body.

If the proper adequate recuperation pause is each time brought about before the responding structures become in any very high degree exhausted, the finger can be so trained that the physiological effects of the responses brought about either more or less directly by a slightly warm stimulus or indirectly by any other stimulus, may be so destructive that the finger will fall away. If, however, the finger is held close to the fire after it is burnt, the fire-response becomes forgotten as the structures which respond gradually become exhausted, and accordingly dissociated.

If the foot becomes very cold, and is gradually warmed, no harm results; while if it is brought suddenly near the fire, the fire-structures which have had their unusually long recuperation pause, now function so very strongly that the physiological effects may be almost the same as if the foot

were really placed in the fire. When the foot is for a long time subjected to the cold stimulus, the cold-response becomes forgotten while the structures for the fire-response are having their long recuperation pause. If the proper training method is applied to the foot, it can be caused to respond alternately as if to fire and ice, either when the adequate stimulus for one of these responses or when that for any other one that is associated with the fire- or ice-response, is presented. The essential condition which must be fulfilled in order to obtain such an alteration of responses is, the adequate pause for one must be filled in with the other response. This is possible only when each of the two responses is at least as long as the adequate recuperation pause for the other.

Ordinarily an indirectly produced response or habit is weaker than an instinct or directly produced response; but if the organism is carefully trained and care is always taken to make the recuperation pause sufficiently long, the habit may be just as strongly expressed as if it were brought about by its most adequate stimulus. For an example we choose a certain unprotected area on the body's surface at which two somewhat blunt compass points of wood can be detected as two when these stimulate points on the skin separated by a distance of two centimeters. A 5 square centimeter tactual stimulus consisting of the same material as the compass points is pressed over this area and allowed to remain 5 seconds, then a pause of 30 seconds is made before the stimulus is again applied, and so on.

Often, after only a few days' training, it is observed that the compass points now, in order to be detected as two, must be farther apart than two centimeters. As long as both stimulate points within the trained area, they are frequently perceived as one indefinite surface. This can mean nothing more than that the 5 square centimeter tactual stimulus brings about simultaneously very similar tactual responses over the entire 5 square centimeter skin area, and that these become so strongly associated in this particular order, i. e., in this temporally superimposed order, that later when a tactual stimulus produces directly one or only a very small number of these responses, such a great number of others are produced indirectly on neighboring areas that a second compass point is, as a stimulus, quite superfluous. The previously established cutaneous pattern is revived by the compass point, which is a comparatively insignificant stimulus. Careful observation teaches that the indirect responses do not occur as suddenly as the directly produced ones; but this time interval

is so very short that it is almost negligible. We can make the statement that, at least in many cases after the direct responses are produced, many of the indirectly produced responses occur so readily that a second stimulus point of the same nature as the first, when this is applied to a neighboring trained area, is very soon a superfluous stimulus. Any stimulus is superfluous if it is applied to the body after the response which it ordinarily produces directly, is, as in this case, already being carried out. If the 5 square centimeter object continually stimulates the area, no habits are established, and on the contrary this becomes an ineffective stimulus; its responses become in a high degree forgotten. This is the case with those bodily areas which come continually in contact with the clothing. Mouth areas which stimulate the tongue have become ineffective as tactual stimuli for the same reason. The eyeball which stimulates the inner area of the eyelid has for the same reason become ineffective as a tactual stimulus. These areas respond normally to other tactual stimuli which are not identical with those which have become ineffective.

If we turn now to the retina, or in other words, to a bodily surface area which is for some reason or another invaginated, and too so well barricaded against foreign stimuli that it responds primarily to certain ether vibrations, these being the stimuli which normally penetrate the schlera, lens, and humors of the eye before reaching the sensitive area in question, we find that the same laws we have been discussing are also applicable in this case. The entire retinal area has often responded to produce the sensation of reddishness, for example, when the eye is closed and turned up to the sky, or perhaps to the sun, and now when the ether vibrations which bring these responses about directly, act on a limited portion of the retina, qualitatively very similar, habitual responses are produced on the neighboring areas; those portions of the retina which are not directly stimulated respond as if directly to the stimulus red.

When the eyelid, or in other words the stimulus red is removed, the retina is directly stimulated, often by one of the many yellows or blues of nature, but it is most often stimulated directly by any one of the great variety of greens of our vegetation. The green which we may at any time see may be any of those which range from greenish yellow to greenish blue. The red- and green-responses must then necessarily become associated in this juxtaposed order, and consequently when one is directly produced the other follows it as an indi-

rectly produced response or habit. The one activitity ordinarily fills in the adequate recuperation pause for the other; thus an alteration of habit-responses is made possible.

The kind of red which we see with the eyelid closed depends upon the nature and the intensity of the light rays which strike the lid; if it is a very intense sunlight we see a reddish yellow, and under conditions of weak illumination we are often able to see a reddish blue. We should then be able to answer the question why it is that the final and most distinctive habitual response which follows any instinctive one produces the most dissimilar psychical state that we, as visual organisms, can experience. For example, the final indirect response to our common saturated red is our saturated green, and the final indirect response to this green is our saturated red.

When a person with closed eyes looks at the sun, and with the eyes still closed turns the head to a dark corner, or perhaps walks into a shady place, he sees a great variety of reds one after another. These reds become associated in this particular order. Moreover, when the observer, with the eyes closed, turns the face to the sun, or walks from a dark place into the intense sunlight, he may see every possible red—from a reddish blue to a reddish yellow. Associations are also formed in this direction. Consequently when the stimulus is our saturated red, this red is the directly produced response, and various reds as habit-responses then occur in the order determined by the length of their reaction times; those with the shortest reaction times occur first, and those with the longest reaction times occur last. This happens to be in the particular order of the similarity of the indirectly produced reds to the directly produced one; the most similar ones are produced first. For example, orange-red and violet-red have the same reaction times, with reference to the stimulus used, and are accordingly produced simultaneously and sooner than violet or orange which have longer reaction times. Since we have frequently seen various blues and yellows, as well as various reds and greens, no significant break occurs in our production of habitual responses; blue and yellow are next produced, then those with still longer reaction times, such as peacock and olive, and finally green.

During the greater part of this time the red-structures have been having their recuperation pauses, so if now the retina is stimulated in any new way, the red responses can be brought about most easily which means in greater numbers. Adequate stimuli for the green-responses are superfluous, because the structures are already responding as if to these stimuli. Fur-

thermore, the stimuli which are ordinarily adequate ones for such as the peacock- and olive-responses are ineffective, because their structures are highly exhausted. If, simply because the visual structures cannot respond in any other way, the red-responses chance to follow the green ones, these become associated in this juxtaposed order. The same thing need only occur when we use any particular green as a stimulus instead of red in order to get an alternation primarily of the red- and green-responses, in which case many of the earlier temporally intervening responses become isolated from or eliminated from the 'red-green-series' in question. We may say that they become dominated over by the red- and green-responses.

A sufficient number of these intermediate responses will always occur, however, to cause the two alternating responses to always be those which are accompanied by the most dissimilar visual psychical states.[2]

If we now turn to the unitary group of movements, we find that these behave in the same way. When two groups occur simultaneously or in close succession, the tendency is manifest for them to occur hereafter frequently in this superimposed or juxtaposed order when the adequate stimulus for only one of these is presented. Temporally superimposed habit-groups have as a rule a very short reaction time. It is for this reason that we use the term temporal superposition instead of simultaneity of occurrence. The directly produced and indirectly produced responses do not start simultaneously, but at least a part of both occur simultaneously. A few elements of the first activity may be beaten before the indirectly produced response begins.

The reaction time for the activity of a cockatoo's crying will now be our immediate subject for discussion. This is an activity, i.e. a group of movements, the adequate stimulus for which is unknown. I will therefore call it x. When the fingers were snapped in a particular way, it was noticed that the bird quickly nodded the head and then immediately afterwards uttered a shrill cry. The reaction time was in this case about 0.60 sec., and it was determined by the temporal duration of the head movement which intervened between the presentation of the stimulus and the cry. The finger snap was not the most adequate stimulus for the cry, but for the head

[2] What is here stated concerning color vision, while it may give some general hints as to the nature of the theory of vision which I shall discuss in a later manuscript, should be looked upon merely as a discussion of the problem of reaction time.

movement which had, at some time or another, become associated with the activity of crying.

The cockatoo, without having been trained to do so, beat occasionally among other unitary groups, a 7-g in the tempo of 0.77 sec. Each element of this group was a sudden stroke of the beak in the air. I choose to make this group a habit. I accordingly merely observed the bird until this particular group was beaten, and then I placed the animal on the floor and allowed it to walk about for one minute. Then I placed it on its perch (the place where it usually beat movements in this tempo) and snapped a stop-watch. The bird responded to this stimulus by suddenly jerking the body. This usually resulted in the bringing of the body, suddenly, into a more erect position. Whenever the bird did not happen to be stimulated in such a way that it beat the desired 7-g just after the body was so jerked, I snapped the watch repeatedly at intervals of five seconds until the 7-g did chance to appear very soon afterwards. When this occurred, a pause of one minute was again made for the 7-g. After this was done a few days the bird regularly beat the 7-g a very short time after the watch was snapped. The only observable activity that intervened was the jerk of the body. The 7-g was thus made a habit. It was now produced not only by its most adequate stimulus, which is unknown and which I will therefore call y, but also indirectly by the watch snap.

After the 7-g had become a well established habit, I snapped the watch, the body was straightened, the 7-g followed, and as soon as this response was finished I snapped my fingers, and then occurred a quick nod of the head, and following it the cry. This chain of activities became so well associated in the order of jerk of the body, 7-g, nod of the head, cry, that when I snapped the watch after an adequate recuperation pause had each time intervened, the responses almost invariably occurred. The reaction time of the cry was in this case, as determined by the stop-watch, 5.36 seconds. Roughly estimated, this time was divided among the various groups of the chain as follows: 0.20 sec. for the straightening of the body, 4.62 sec. for the 7-g, and on an average 0.81 sec. for the nodding of the head, and the very short time which intervened between this movement and the last element of the 7-g.

The activity of crying was a habit-group to begin with; for it was already invariably preceded by the nod of the head. It became merely a more strongly established habit when it became associated also with the 7-g. It finally became produced not only directly by its most adequate stimulus x, and indi-

rectly by the stimulus finger snap, but also indirectly by the y and the watch snap. The activity of crying accordingly occurred more frequently than previously. The training method was further applied to associate a great variety of groups with the 7-g which was regularly followed by the nod of the head and the cry. The reaction time of the cry could with a high degree of certainty be predicted if the stimulus only was known. It was merely necessary to consider the number and tempos of the movements of the various groups which regularly intervened between the presentation of the stimulus used and the occurrence of the cry.

Generally, when any unitary group is beaten, and an adequate recuperation pause for it is made, during which the animal is not allowed to beat any group in the same tempo, this group is the first one to be beaten after the pause. Since this is the case, the likelihood that the direct response to the stop-watch which snaps every five seconds will chance to be concluded just as the activity of our primary interest begins, is very much increased. The watch must not be snapped incessantly. If it is so snapped, it will become ineffective for bringing about even its most immediate response. The observed immediate response to this stimulus was very short (about 0.20 sec.) and the adequate recuperation pause was also very short, the pause being not longer than three seconds. It was therefore possible to snap the watch every five seconds without exhausting the structures which were responsible for the produced visible activity. If this direct response to the snap of the watch happens to be concluded just as the 7-g—or just as some activity which is associated with the 7-g—starts, the association is, as we have seen, more or less definitely established.

Since the most complex activities, such as the fire-, ice-, tobacco smoke-, green-, red-responses, etc. behave in just the same general way as the simple unitary groups, I have ventured to postulate the group-movement as the behavior correlate of every psychical state.

The fire-response I have spoken of as complicated. This merely means that a great variety of unitary groups are being beaten simultaneously, and serially. The stimulus fire produced directly a great number of groups, a large number of which are qualitatively similar, even though they may be quantitatively very different. They are qualitatively the same since they are beaten in a constant tempo, direction, and relatively constant amplitude of movement, and they are quantitatively the same or different in the sense that they contain

the same or different numbers of elements. For example, one of these postulated groups may contain two elements in the tempo of a hundredth of a second, and another which is beaten in the same tempo may contain fifty elements. The duration of the latter group is twenty-five times that of the former. Let us say that the 2-g is associated with a particular activity which may be called the a-response, and that the fifty-group is followed regularly by another response which may be called the b-response. The reaction time of the b-response would accordingly be twenty-five times that of the a-response; and if these groups start simultaneously, they cannot terminate at the same time.

I have ventured to speak of the behavior correlates for colors, such as red, in terms of the unitary group. I have called these the red-groups. These are qualitatively similar, but they may be widely different quantitatively. If we then fixate a piece of red paper, the stimulated visual substances beat the red-groups in great numbers. These are temporally superimposed. The shortest ones terminated must have their adequate recuperation pauses before they can be beaten a second time. And they may occur a second time before the longest red-groups are completed, i. e. provided the stimulus remains present. With any red-group there may be associated any other response. Of the possible visual responses which may be associated with the different red-responses, may be mentioned the blue-, yellow-, orange-, violet-, peacock-, olive-, green-groups, and so on. The qualitatively most dissimilar groups, i. e. the green-groups, may be associated with the longest, or under conditions, the shortest, or medium red-groups. In other words, the reaction time of the green-groups as habits may be anything the visual organism may be trained to have. The eye appendages such as the eyelid, lashes, etc., serve to make this reaction time short. This and many other things which a theory of visual sensations should explain, will be brought out in a later manuscript on "Visual Instincts and Habits."

AN ANALYTIC STUDY OF VISUAL PERCEPTIONS*

By ANNA SOPHIE ROGERS

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CHAPTER I

INTRODUCTION

The study of perception has had a long and involved history,—a history which extends, as we may suppose, far beyond the years of written record. The obvious dependence of life upon the use of the senses must have suggested one of the very earliest of all the human problems concerned with mind; and in due time, as we know, primitive curiosity and conjecture came to be supplemented by centuries of reflective and scientific inquiry into man's perceptual means for knowing the world. The implication of mind, however, in the direct apprehension of present objects has not by any means limited the study of perception to the psychologist. The philosopher, the logician, the anatomist, the physiologist, and the general student of life, as well as the psychologist, have derived problems from, and erected theories upon, the facts of perception. These facts have had their bearing upon the character, the trustworthiness, and the limitations of knowledge. upon the substance of reality and the nature of truth, upon the construction and the operations of the senses, and upon the mutual relations of the organism and its surroundings.

*From the Psychological Laboratory of the University of Illinois.

Our own study is to be limited to the psychological aspects of perception. All of the other aspects we shall leave out of account. And within psychology itself the field of perception is so broad and the problems so diverse that we shall be obliged to propose still further restrictions upon the range of our inquiry. It is principally of the *analysis* of certain perceptions that we shall treat. We have chosen this part of the whole problem both because analysis has been neglected, even in experimental treatises, and because a description in analytic terms seems to us to be fundamental to any scientific treatment of mind.

In the following investigation we shall first approach our subject from the historical side to distinguish the old from the new and to set our own problems and methods in a clear and significant relation to others.

A. The Meaning of the Term 'Perception'

1. *Historical summary.* Until recent times two widely divergent views of perception were current in the history of psychology; two views which show a general correspondence to the ancient dualism of activity and passivity. As applied to mental facts at large, the one side of the dualism conceives of mind as an agent or power, actively manifesting itself in the world; the other side conceives of it either as a product or as a reflection of nature, but without dynamic or creative attributes. As regards perception, the one view presents a faculty by which the mind or the soul puts forth its power in the apprehension of surrounding objects; the other view presents a kind of knowledge, mediated by the senses and constructed according to a principle of association or to some law of bodily functions. The two views are to be traced through the long history of reflective thought, the emphasis placed now upon the one side and now upon the other, according to the temper of the philosophical, theological, and scientific theories of the time.

The first way of treating the problems of perception has been common since the time of Plato; the second attained its greatest prominence in the eighteenth century through the development of the doctrine of "sensationalism."

Plato[1] and Aristotle[2] are among the earliest of western philosophers to consider perception as a faculty whence the mind or soul derives its knowledge of the physical world. The inlet of this knowledge

[1] Plato, *Theaetus* (Ed. I. Burnet, Oxford), Sec. 151-152; *Republic* (Ed. Stallbaum). V. xxi; VII, vii.

[2] Aristotle, *De anima* (Ed. F. A. Trendelenburg), II, iii-xii; III, i-ii.

was by way of the sense organs, through which impressions passed. These impressions, once received, were organized by the soul (Plato) or the common sense (Aristotle).

The Platonic and Aristotelian view of perception was destined to exert an influence for many centuries. Restatements of the doctrine are to be found in Descartes, in Locke, and in Leibniz. In the system of Descartes,[3] perception is called a "function," but "function" is only the older "faculty" in disguise. And as with Plato, so with Descartes, the soul is the unifying agent for the various impressions of sense. Leibniz[4] likewise adheres to an interpretation of the soul in terms of faculties. The entire universe is composed of dynamic monads, which are ordered from the lowest to the highest according to their ability to perceive. In the human being, the monad or soul becomes a means of unification for all activities,—a conception which is strongly reminiscent of Plato and Aristotle. Perception, which ranges from obscurity to clarity, is regarded as one of the innate activities of the monad. Like Descartes and Leibniz, Locke[5] regards perception as an activity or power. He maintains that it is the primary faculty for receiving knowledge about the physical world. Not every impression upon the sense organ, however, gives rise to a perception. Whether or not it does, depends upon the frequency of its occurrence, and also upon the mind's preoccupation with other ideas. For Locke, however, perception is more than a faculty or power; it is also the material of knowledge. Through the medium of sensations the organism perceives objects as possessing the primary qualities of extension, motion, number, and figure, as well as the secondary qualities of sound, color, and the like.

By all these writers, then, perception has been regarded as a capacity, power, or faculty of mind, with the qualification that in Locke, although defined as a faculty, it is also regarded as a kind of knowledge originating in "sensation." After Locke, the notion that perception results from the combination of sense-impressions received elaborate exposition at the hands of the "associationists." Hume expressed this view when he said concerning perceptions of space and of time that "there is another very decisive argument, which establishes the present doctrine concerning our ideas of space and time, and is founded only on that simple principle, *that our ideas of them are compounded of parts which are indivisible.*"[6]

Much later, Bain[7] enlarges the meaning of perception beyond that of the sensationalists. He departs from the interpretation of the latter both as to composition and as to function. Besides bare sensory impressions, muscular feelings are also included in the materials of perception, and the process becomes more highly intellectualized than before. The criterion which now determines whether a process is intellectual or sensory is discrimination, or the feeling of a difference. The fundamental fact of perception—namely, that it is the result of association,—signifies that several constituents are present and

[3]Descartes, R., *The passions* (Ed. C. Adam and P. Tannery), Sec. xvii, xix-xxxv.

[4]Leibniz, W. G., *Monadology*, 1714, Sec. 14, 19, 21.

[5]Locke, J., *Essay concerning human understanding*, London, 1823, Bk. I; Bk. II, chap. 9.

[6]Hume, D., *A treatise of human nature*, 1748, II, iii.

[7]Bain, A., *The senses and the intellect*, N. Y., 1874, 364; *The emotions and the will*, N. Y., 1876, 549.

are accompanied by a feeling of difference between the successive or coexisting impressions. Bain anticipates James in this distinction between perception and sensation, making the difference one of kind as well as of degree of knowledge. James maintains that perceptions and sensations resemble each other, but are not identical. Perception differs from sensation in that it implies "consciousness of farther facts associated with the object of sensation."[8]

The principle of associationism was adopted by the French psychologists, Condillac and Bonnet. Condillac worked out an elaborate system of sensationalism. Every capacity of the soul is derived from sensations, between which are established associative connections.[9] He anticipates Herbart's mechanics of ideas in assuming that some impressions and presentations are favored by desire and attention, while others are kept in the background. Like Condillac, Bonnet derived all mental life from sense impressions, but instead of resulting from the association of sensations, everything was to be interpreted in terms of nervous mechanisms. The description of mind becomes a "psychology of the nerve-fibres."[10] Perception originates from simultaneous and successive excitations which give rise to sympathetic movements in connected or contiguous tracts.

In the German psychology of the eighteenth century, accounts of perception were given both in terms of faculty, as expounded by the philosopher Christian Wolff, and in terms of the sensationalism of England and France. Later, in Herbart,[11] perception—like all other mental phenomena—was reduced to the single, primary act of presentation (*Vorstellen*). It was the result of fusions and complications. Herbart's emphasis upon the fluid and the dynamic aspects of mind has exerted a strong influence in the subsequent scientific period. But it is principally Wundt's insistence upon mental analysis in terms of process, that has given us the doctrine of perception as a typical mental formation whose members are the simple processes of sensation and feeling.

2. *Recent and contemporary uses of 'perception.'* As in earlier times so also during the scientific period, the word 'perception' has been put to two unlike uses,—uses which are similar to, but not identical with, the older dualism. First, it is treated as one of the major *functions* of the mind after the pattern of the active powers or 'faculties,' and, secondly, it is more passively regarded as a *composite* of individual processes. Functionally treated perception becomes a performance, an accomplishment, or the discharge of a service;[12]

[8] James, W., *The principles of psychology*, N. Y., 1890, II, 77.

[9] Dessoir, M., *Abriss einer Geschichte der Psychologie*,. Heidelberg, 1911, 114.

[10] Klemm, O., *Geschichte der Psychologie*, Leipzig, 1911, 98.

[11] Herbart, J. F., *Lehrbuch zur Psychologie*, 1834, Sec. 55-56.

[12] These interpretations agree in general with the definitions of function as proposed by Ruckmich, C. A., (The uses of the term function in English textbooks of psychology, *Am. J. of Psychol.*, 1913, xxiv, 99); and by Dallenbach, K. M., (The history and derivation of the word 'function' as a systematic term in psychology, *ibid.*, 1915, xxvi, 473).

more passively and descriptively regarded it is an organic whole, analyzable into component parts. On the side of function the perceptual performances may be purely mental, as knowledge of environment, cognition of the world,—or it may be a psychophysical function which the whole organism expresses in overt or inhibited action. The first is the cognitive, the second the biological or psychophysical function of perception.

Among the writers interpreting perception as a composite of elementary processes,—to discuss first the analytical use—are to be found Wundt, Titchener, Angell, James, Binet. Perception thus considered is organized, *i.e.*, its constituents are arranged in definite configurations and patterns. The exact nature of these constituents varies from author to author, but there is a general agreement as regards sensational and imaginal processes, both of which vary from individual to individual and from perception to perception. Not only do images arise with sensations to form perceptions, but affections are, according to Wundt,[13] also regarded as constant, component parts. This affective component is less regarded in perception by Titchener, Angell, and James. A "pure" perception would be composed of sensations alone, but this seldom exists. There are usually imaginal accompaniments, the kind depending both upon individual constitution and upon the previous setting of similar experiences.

Again, there are other writers who propose another kind of constituent for the perceptual complex, a formal or 'funded' quality.[14] Over and above the sensational and imaginal processes, these writers profess to find something which determines the perceptual complex and which is 'subjectively' added. The chief exponents of this theory have belonged to the Austrian school, among whom are Ehrenfels, Meinong, Cornelius, and Witasek. The real value of their contention lies, not in the discovery of new and unique members or factors in the perceptual complex, but upon the fact—overlooked by traditional sensationalism—that the perception has characteristics, properties, and functions which distinguish it and which disappear when the complex undergoes analysis.

Where perception is thus regarded process-wise as a group of integrated and organized members, it is obvious that its cognitive aspect,—its meaning,—has separately to be considered. The relation of process to meaning in perception has been variously conceived. Some writers agree in regarding images as the most important factor for giving purport to the complex. According to the Wundtian doctrine of 'context,' as expounded by Titchener,[15] it is the background (either imaginal or sensational) which gives significance to the perception.

When regarded functionally, perception wears a different aspect and it provokes a different kind of scientific inquiry. Let us consider it first as a mental function and afterwards as a psychophysical func-

[13]Wundt, W., *Grundzüge der physiologischen Psychologie*, Leipzig, 1911, III, (6th ed.), 296.

[14]See Bentley, M., The psychology of mental arrangement, *Am. J. of Psychol.*, 1902, xiii, 269.

[15]Titchener, E. B., *A textbook of psychology*, N. Y., 1915, 367. *Cf.* Angell, J. R., *Psychology*, N. Y., 1908, 156.

tion. The first kind finds an exponent in Stout, who describes perception as "essentially cognition,"[16] which signifies that the mind acquires knowledge of objects by means of a cognitive performance. Stout has been influenced by James; but James was interested in the biological or psychophysical as well as in the cognitive functions of perception,[17] according to which the response of the organism or at least the motor discharge forms a part of the perception as essential as are the afferent impulses. Such a view is sustained, *e. g.*, by Dewey, who, in opposition to Stout, defines perception as primarily a fact of action, not one of cognition.[18] The perceived objects are arranged about our bodies as centers and our field of perception increases and varies with the growth and needs of the organism. From action to adjustment is a short step, and it has become common for writers whose main interest lies on the biological side to affirm that the adaptation of the organism to its surroundings is the primary function of perception.[19]

This emphasis laid upon the functional aspect of perception recurs likewise in studies in comparative and genetic psychology and in behaviorism. Watson, who stands for behaviorism as a substitute for psychology, speaks constantly of the "sense functions," which really include perception, as shown by some of the problems suggested under such headings, *e. g.*, "the rôle of vision in daily life," and "the response to ordinary sounds in the animal's environment."[20] Baldwin,[21] too, in his statement of genetic problems, emphasizes the fact of "functional epochs," or the child's acquisition of knowledge through direct experience.

We may, then, summarize our historical sketch by remarking upon the persistence through many centuries of the 'active' and 'passive' views of perception. Until recent and more scientific times perception was either a power, a faculty, of the soul, or else the mere reception of 'impressions' to be connected and elaborated by 'association' or by the nervous system. Under the conjoint influence of the other sciences and of experiment within psychology itself, the dualism of active and passive has been modified, but it still persists in the functional and analytical accounts of perception. The one looks upon perception as a mental or psychophysical performance, of use either to knowledge or to the organism; the other describes it in terms of integrated processes.

With these gross distinctions, historical and current, in view, we turn to an inspection of the actual problems and methods which are to be found in the recent literature of our

[16]Stout, G. F., *A manual of psychology*, N. Y., 1899, 241.

[17]James, W., *The principles of psychology*, 1890, II, chap. xix.

[18]Dewey, J., Perception and organic action, *J. of Philos., Psychol., Etc.*, 1912, ix, 645.

[19]Judd, C. H., What is perception? *J. of Philos., Psychol., Etc.*, 1909, vi, 36; Aaronson, I., Perception, *ibid.*, 1914, xi, 37.

[20]Watson, J. B., *Behavior*, N. Y., 1914, 33-36.

[21]Baldwin, J. M., *Mental development, etc.*, N. Y., 1895, 1ff.

subject. But in order to describe these problems and methods we must first glance at the classifications of perception to be found among modern psychologists. Our inspection of kinds, problems, and methods, should be a useful means to orientation within the field of our own experimental studies which we are presently to enter.

B. Perception in Modern Psychology.

1. *Kinds and classes.* In order to discover an adequate basis of classification, we may review the treatment accorded our subject by such systematic psychologists as Wundt, Külpe, Titchener, Angell, Pillsbury, Stout, and Ebbinghaus. Consonant with our historical summary, we find, in these systems, that perceptions are classified either (a) as modes of integration of component processes or (b) according to the kinds of knowledge which they mediate.

(*a*) *Classification of perceptions as modes of integration.* Wundt is one of the chief exponents of a distinction made in terms of the manner of combination of the elementary processes. Perceptions are, for him, fusions, complications, and assimilations.[22] An association of elements by fusion may be intensive or extensive. By intensive fusion he means that interconnection which exists between processes by virtue of their qualitative relationship, *e. g.*, the clang. This kind of affinity between mental processes exists only among those arising from the same sense-department and from sensory stimulation. The term 'fusion' is extended to other forms, spatial and temporal, where it is designated as extensive. If the perception, on the other hand, arises from a union of sensations from different sense-departments, as a perception of water from visual and cutaneous processes, then it is known as a complication. These two modes of integration account for perceptions that are composed of only present experiences. There are, however, other perceptual complexes in which reproduced experiences play an important part, as the perception of any familiar object which contains more than the bare sensory processes. Whenever image combines with sensation to form a perception, the integration is known as an assimilation.

Külpe and Titchener also classify perceptions according to the mode of integration of the component factors. The modes of perceptual integration according to Külpe differ but slightly from those of Wundt. Külpe's classification includes fusion, colligation, and association.[23] Fusion is defined as a qualitative connection between elements when they are spatially and temporally identical, *e. g.*, if two notes were simultaneously given, the tones would be temporally identical but qualitatively diverse. Fusion, then, from Külpe's point of view, is only one (the intensive) phase of Wundt's fusion. The spatial and temporal perceptions are designated by Külpe as colligations. For example the tone a^1 repeated with alternately long and short intervals, would be an instance of identical quality but of different temporal

[22] *Grundzüge*, III, (6th ed.), 500ff.
[23] Külpe, O., *Grundriss der Psychologie*, Leipzig, 1893, 284ff.

relations and it would fall accordingly into a temporal colligation, rhythm. A pattern of colors would illustrate the spatial kind of colligation. Furthermore, elements not only unite qualitatively, spatially, and temporally, but they integrate also because each tends to establish a relationship between itself and other processes. So arise associative combinations.

According to Titchener, perceptions are distinguished as qualitative, spatial, temporal, and mixed.[24] The first three would all be grouped as fusions, intensive and extensive, by Wundt, save that Titchener's qualitative complexes also include Wundt's complications, and Titchener's mixed type is virtually equivalent to Wundt's assimilation.

In general, then, with slight limitations and expansions of terminology, Wundt, Külpe, and Titchener make similar classifications of perception. Their distinctions between kinds or types depend mainly upon the capacity of the sensory processes to integrate qualitatively, spatially, or temporally, or upon the fact of images attaching themselves to sensations to form perceptions.

(b) *Classification of perceptions based upon kind of knowledge.*

A classification of perception from this point of view depends upon an interpretation of it from its functional aspect. Stout, Angell, Pillsbury, and Ebbinghaus treat it in this manner. Stout enumerates five kinds: perception of external or physical reality, of space, time, causality, and 'thinghood.'[25] A glance at these terms will disclose the emphasis placed upon the cognitive function. In order to have any perception at all there must be some external or physical object, even the body or its parts becoming external to the self when cognized. Besides being external, every object must possess unity, identity, and independence, by virtue of which it is perceived as distinct from every other object. This distinctness is designated 'thinghood.' Furthermore, an object, besides being external to the organism and distinct from every other object, may also be thought of as causality, or as the result of a gradual, practical adaptation, whereby through past experiences the organism becomes aware of the object's efficiency or inefficiency. In all of these categories of perception the importance of knowledge or information about objects is the outstanding factor. Likewise, perceptions of space are such as have to do with information about some physical object, for space is a matter of relations in position and distance, and position and distance must pertain to objects. What is true of spatial perceptions is also true of temporal, *i. e.*, time bears relation to something, as to the past, present, and future.

Angell, Pillsbury, and Ebbinghaus likewise draw distinctions between the large classes of perception according to the kind of knowledge derived. Angell, however, limits all perceptions to two main classes, spatial and temporal. Every perceived object implies a spatial and a temporal order. Each class has its own peculiar function: by means of spatial perceptions the organism becomes accommodated to a three-dimensional world; by means of temporal perceptions, to a "world of sequential events."[26] Thus, by virtue of knowledge concerning the outside world acquired through the perceptual functions the living being adjusts itself to its environment.

Pillsbury does not vary much from Angell's position. The chief concern is, he says, the tracing of "factors that aid in the transforma-

[24] *Op. cit.*, 389.
[25] *Op. cit.*, 312.
[26] Angell, J. R., *op. cit.* N. Y., 1908, 172.

tion of the sensations into objects."[27] During this procedure, it is also necessary to keep in mind the way in which "elementary mental states come to mean that which they are not." For him, the meanings, or informations, are of much more importance than the formation or integration of the perception. The kinds of meaning, or knowledge, which are obtained by way of the perceptual process are fusions, and spatial and temporal relations. Besides these, the mind may also become aware of movement of change, and of rhythm. The former is related both to space and time, the latter primarily to time. We see, then, that these types of perception are not essentially different from those of Angell and Stout. They stand related to those of the former in that fusion, movement, and rhythm are perceived as parts of a spatial and temporal order; to those of the latter by virtue of the fact that in so far as adjustment and reaction to objects greatly aid in the perception of them, objects as perceived, whether as fusions, movement, or rhythm, must possess physical reality, causality, and 'thinghood.'

Finally, the classification of Ebbinghaus, although it appears to be of the first or integrative kind, is at bottom functional. The general (*gemeinsame*) or formal attributes, unity, identity, plurality, difference, and the like,[28] which Ebbinghaus assigns to sensations, are really functional marks, so that his account of perception is really not at all a description of mental processes but a description of the kinds of knowledge to which perceptions give rise. Ebbinghaus has therefore to be grouped with Stout, Pillsbury, and Angell, rather than with Wundt, Külpe, and Titchener.

In general, then, it may be said that those psychologists who base their classification of perception upon kind of knowledge derived are emphasizing the functional aspect. Furthermore, this division of the types of perceptions may be as various, with respect to terminology, as the relationships of object to object and of object to organism may suggest. On the other hand, those who have distinguished classes of perception upon the basis of integration have placed the main emphasis upon the fact that perception is an organized complex made up of elementary processes.

The recent insistence in some quarters upon the adaptive functions of mind leads the student of perception to look for a third kind of classification which should take into account the facts of organic adjustment. Systematic work of this kind seems, however, not to have been done. Where general terms have been demanded by the biologizing psychologist, the older, cognitive distinctions seem to have been transferred,—by a comfortable logic,—to the ecological kind of function.

2. *Problems of perception.*[29] With this historical back-

[27]Pillsbury, W. B., *The fundamentals of psychology*, N. Y., 1916, 269.

[28]Ebbinghaus, H., *Grundzüge der Psychologie*, Leipzig, 1911, I, 442.

[29]For a basis of determination of the problems and methods of perception, approximately 150 investigations have been examined. For this purpose, the studies upon perception reported in the following

ground in view, let us turn to the empirical problems which the subject of perception has presented, and then proceed to the methods employed for their solution. The problems may be grouped under the following eight headings:

i. Dependence of perception upon variations of stimulus as to its (a) kind, (b) temporal peculiarities, (c) spatial arrangement, and (d) degree; perception is either (1′) analyzed in terms of process or (2′) referred in terms of meaning to variations in stimulus.

ii. Dependence of perception upon organic conditions: (a) general, and (b) local.

iii. Dependence of perception upon the general state or condition of mind.

iv. Relation of perception to organic movement.

v. Deranged perceptions: synaesthesias, illusions, hallucinations.

vi. Relation of perception to thought.

vii. Nature of perception in animals.

viii. Development of perception: (a) phylogenetic, and (b) ontogenetic.

An examination of the recent experimental literature will serve both to define and to illustrate the numerous perceptual problems which have already been formulated. We shall take them in order.

i. Dependence of perception upon stimulus

The problems of perception which depend upon the control of the stimulus present many and several phases, since the stimulus may be widely varied with respect to its various characteristics. The task then resolves itself into (1′) the analytical description of the sensational and imaginal processes making up the perception under variations of stimulus, or (2′) the correlation of change in meaning with change in stimulus. Either of these modes of interpretation of results may be the aim of the investigation under any of the four possibilities of modification which have been distinguished.

(a) Dependence of perception upon change in kind of stimulus. Under this sort of quest the three remaining aspects of stimulus, time, arrangement, and degree, are kept as constant as possible, while modifications in kind are made under control, in order to determine any difference in the perception which may result. The investigation by Kemp[80] into tonal fusion furnishes an excellent example of this

periodicals were scrutinized: *Am. J. of Psychol.*, 1903, xiv—1916, xxvii; *J. of Animal Behav.*, 1911, i—1916, vi; *J. of Philos. Psychol., Etc.*, 1910, vii—1916, xiii; *Psychol. Rev.*, 1908, xv—1916, xxiii; *Brit J. of Psychol.*, 1904-05, i—1915-16, viii, Pt., 3; *L'Annee psychol.*, 1910, xvi—1914, xx; *Arch. f. d. ges. Psychol.*, 1909, xiv—1915, xxxiv; *Psychol. Stud.*, 1905-06, i—1907, iii; 1911-12, vii—1913-14, ix; *Psychol. Index*, 1915, xxii (all references quoted upon perception); and many other volumes and periodicals not here quoted.

[80] Kemp, W., Methodisches und Experimentelles zur Lehre von der Tonverschmelzung, *Arch. f. d. ges. Psychol.*, 1913, xxix, 139.

part of the first problem. Two notes of unlike vibration rates were presented to the observers, who were instructed to compare the tonal complexes as regards degree of fusion. The introspective reports, however, were not highly analytical.

Experiments in which mere changes in meaning are reported, and in which the aim is to refer these changes to modifications in the character of the stimulus are illustrated by Woodrow's[31] study of rhythm. The influence of the intensive and temporal factors was minimized or eliminated, thus producing the most favorable conditions possible for correlations between qualitative changes in perception and variations in the nature of the stimulus.

(b) Dependence of perception upon the temporal properties of the stimulus. Perceptions of rhythm and intervals of time are directly influenced by any temporal modifications in the stimulus. Experiments which illustrate this were devised by Ross[32] and Wallin.[33] In the first investigation, a series of ten clicks, all at constant intervals with one exception, wherein the time was shortened, was provided. The task of the observer was to detect the exceptional interval. The perception of this particular duration was described only by its detection, when compared with another, constant time, *i. e.*, it was described only in terms of meaning, not of process.

On the other hand, Wallin determined not only changes in meaning, but also the processes which underlie the perception. The observers were asked to find a tempo midway between two others, one fast and one slow. With the quantitative results were also recorded comments made by the observers upon the aids employed in the perception and the determination of the temporal rate. Wallin reports, *e. g.*, that "four believed that they based their estimations on the immediate impressions," "practically all the subjects made use of the kinaesthetic factors," or again, "only three were conscious of using any visual imagery."[34] Although these comments are not true introspections made in terms of process, they show more of a tendency in that direction than the reports of the observers in Ross' experiment.

(c) Dependence of perception upon the spatial arrangement of stimulus. The possibilities of modifications in the spatial pattern of stimulus are illustrated in many investigations into those perceptions which owe their configurations and meanings primarily to the spatial arrangement of the exciting agency, *e. g.*, perceptions of lines, depth, size, and form. Such an experiment as Cook carried out upon the cutaneous estimation of filled and unfilled space, is a case in point. Aesthesiometers for punctual and continuous impressions were used.[35] The problem—the determination of the amount of illusion present in the comparison of filled and unfilled spaces—assumes a change of perception corresponding to a change in the spatial relationships of the stimulus.

We find, however, other investigators describing the perception both as meaning and as process. In an experiment upon reversible

[31] Woodrow, H., Rôle of pitch in rhythm, *Psychol. Rev.*, 1911, xviii, 54.

[32] Ross, F. B., The measurement of time-sense as an element in the sense of rhythm, *Psychol. Monog.*, 1914, xvi (No. 69), 166.

[33] Wallin, J. E. W., Experimental studies of rhythm and time, *Psychol. Rev.*, 1912, xix, 271.

[34] *Ibid.*, 295.

[35] Cook, H. D., Die taktile Schätzung von ausgefüllten und leeren Strecken, *Arch. f. d. ges. Psychol.*, 1909-10, xvi, 442.

drawings, Becher,[36] *e. g.*, has discovered not only that different meanings arise under spatial differences of stimulus but also he has identified the mental processes which correspond to these differences.

(d) Dependence of perception upon the degree of stimulus. Such an investigation as was conducted by Arps and Klemm[37] upon the relation of intensity to the localizing of sound will illustrate this point. The source of the sound was a tuning fork, which could be moved in either the median or transversal plane of the head. The sound itself was transmitted to the observer by means of a telephonic connection. The observer's task was to compare one sound with another of like physical intensity but in a different position, or with a sound at the same distance as the first, but of unlike intensity. Since the duration and equality of the sound were constant, its intensity was the determining factor for localization. Since the investigators were concerned with spatial localization, their problem was of the second or cognitive type.

ii. Dependence of perception upon organic conditions: (a) general, and (b) local.

(a) The perception of an object may be greatly influenced by the general state of the organism. For example, one experimenter, Jones,[38] permitted himself to be anaesthetized with chloroform in order that he might introspectively observe the effect upon his mental processes. He found not only that perceptions were the first mental processes to drop out, but that these also changed as they disappeared. For instance, he says that "all movements made appeared to be much longer than they actually were," that "winking gave the peculiar feeling of a great curtain slowly shutting out the light and as slowly rolling back again," and numerous other instances of perceptions which were modified by the anaesthetized condition.

(b) Every perception depends upon the condition of its particular sense organ, consequently modifications of local organic conditions result in modifications of the mental correlates. Perceptions which indicate directly such an influence are the difference in the perception of size by different parts of the retina, the perception of the position of objects with the head held at various angles, and the different perceptions of the same pattern upon various parts of the skin. The first depends upon the local conditions of the retina; the second, upon organic conditions within the head; the third upon the distribution and 'local sign' of the pressure organs in various parts of the skin. For illustration, we may cite Stevens' experiment upon peripheral vision.[39] By use of one of the psychophysical methods, the author determined the perceived difference in the size of the objects at different parts of the retina.

iii. Dependence of perception upon the general state or condition of mind.

States of this sort are attention, expectation, doubt, hesitation, and

[36]Becher, E., Ueber umkehrbare Zeichnungen, *Archiv. f. d. ges. Psychol.*, 1909-10, xvi, 397.

[37]Arps, G. F., and Klemm, O., Untersuchungen über die Lokalisation von Schallreizen, *Psychol. Stud.*, 1912-13, viii, 226.

[38]Jones, E. E., The waning of consciousness under chloroform, *Psychol. Rev.*, 1909, xvi, 48.

[39]Stevens, H. C., Peculiarities of peripheral vision, *Psychol. Rev.*, 1908, xv, 69.

deliberation. The subject is so predisposed when the stimulus is applied as to affect his perception. In reporting an experiment upon the influence of expectation upon auditory localization, Geissler says[40] "in our method the greatest importance must be laid on the instructions given to the observers and the subsequent reports demanded from them." In other words, he had previously prepared his subjects to perceive the object in a certain position and his task was to determine in how far this mental set affected the localization of the sound.

iv. Relation of perception to organic movements.

In the three groups just reviewed, the task of the investigator ended when he had established and described a perceptual complex under certain conditions of stimulus, body, or mind; but in the fourth group emphasis is placed less upon sensory and imaginal components of the perceptual consciousness and upon conditions than upon resultant and motor tendencies which are sometimes alleged to be factors essential to perception.[41] The following quotation from Judd, who writes in terms of 'reaction' and 'adjustment,' will make the matter clear "The simplest perception of an object which is presented to the eyes contains a great deal more than sensory elements of which it is composed. It consists of certain forms of arrangement and certain tendencies toward reaction which must be recognized by any student who would work out an adequate account of these processes."[42] Partial or total 'adjustments' are then, for Judd, necessary factors in perception.

From what has just been said concerning the relation of perception to organic movement, it is evident that such writers as Judd are less concerned with the perception itself than with events and occurrences concomitant with, or subsequent to, the perceptual complex, with events which are really the final result and not the components of perception. The chief interest in perception, from this point of view, is a consideration of it as the accommodation of the organism to its surroundings.

v. Deranged perceptions; synaesthesias, illusions, hallucinations.

Some of the problems developing from the study of deranged perceptions are: (a) a description of the processes which comprise the complex; (b) a description of meanings; and (c) an explanation of the cause of such perceptions. This last problem belongs primarily under the second group of problems, or the dependence of perception upon organic condition. A description of a deranged perception in terms of process is difficult, because of the inability and the limited reliability of introspective reports under conditions where such derangements occur. But referring again to the experiment by Jones[43] upon the influence of anaesthetics, we find from his own observations that the distorted perceptions are the result of disturbed sensory processes, *e. g.*, he reported that, at first, the visual sensations were clearer and more intensive, while auditory and tactual processes decreased in clearness, and his deranged perception of movement was the probable sequence of the low intensity of tactual sensations.

[40]Geissler, L. R., Sound localization under determined expectation, *Am. J. of Psychol.*, 1915, xxvi, 269.

[41]Dewey, J., *op. cit.*, maintains that perception is the result of incipient and partial organic responses.

[42]Judd, C. H., *op. cit.*, 40.

[43]Jones, E. E., *op. cit.*, 51.

vi. Relation of perception to thought.

The relations of perception and thought are to be sought for on the side of common properties either of process or of function. With regard to composition, we might expect to find like components and even similarities of integration. Thought would then simply become a complex involving greater elaboration of meaning than perception, due to its greater complexity of composition and differences of function of the component processes. Thought would, from this point of view, be distinguished from perception by degree of meaning rather than as a different kind of mental phenomenon. On the side of function common attributes and properties of the two activities must be taken into account. If perception is considered as cognitive, and thought as elaborative, then there is a wide distinction; but if we look upon perception as accomplishing something more than mere apprehension, then we find that the two functions again approach each other in nature. The problem, however, has never received comprehensive treatment.[44]

vii. The nature of perception in animals.

Here we find two main problems; first, a description of the mind of organisms below man based upon a comparison with the human mind, and secondly, the relation of animal performances to perception. An experiment by Johnson[45] will illustrate the first, in which the ability of monkeys and chicks to discriminate lines or striae of different widths was made the subject of investigation. Limens of discrimination were found for these animals as well as for man. Certain other persons, however, who are chiefly interested in the animal's performance lay no stress upon the analysis of the perception itself. A description in terms of performance, behavior, or response which is directly correlated with physical conditions, suffices for their purposes. We find Watson [46], *e. g.*, taking this extreme view.

viii. Development of perception; (a) phylogenetic and (b) ontogenetic.

The first group of problems listed here presents a large field and a wide range. The investigator who enters upon such a task as determining the development of perception in the animal phyla must possess much ingenuity and versatility in pursuing the many problems which present themselves and in devising methods for their solution. Here would be listed such problems as the modification of perceptual complexes from the lowest to the highest living form, a comparison of differences in perception with differences of nervous system, and a comparison of perception with other mental complexes at the various stages of development in the animal series. The ontogenetic development of perception, on the other hand, does not include such a wide scope, but limits itself to the study of perception within one organism from birth to maturity. Judd and Cowling[47] present a

[44]F. Aveling (Relation of thought-process and percept, *Brit. J. of Psychol.*, 1911, iv, 213) considers the interrelations of thought and the sensational processes as the problems which underlie the relation of thought and perception.

[45]Johnson, H. M., Effective differences in width of visible striae for the monkey and the chick, *J. of Animal Behav.*, 1916, vi, 169.

[46]Watson, J. B., *op. cit.*

[47]Judd, C. H., and Cowling, D. J., Studies in perceptual development, *Psychol. Rev., Monog. Sup.*, 1907, viii, No. 34, 349.

meagre account of the gradual development of a perception in their experiment on the rate of learning to reproduce certain outlined figures. The reproduction was performed, first, with the eyes closed; secondly, with the eyes open and the drawings hidden, and thirdly, under visual control both of the movements and of the drawings. We have already noted (Sec. *iv*, above) that Judd is primarily interested in perception as described in terms of 'reaction' and 'adjustment,' and so again we mark the characteristic failure of introspective description in the experiment just mentioned.

If we glance in review, then, over the problems which are concerned with perception, we see that they come under the eight headings enumerated, which may be further divided, in turn, into two large groups. The first would include the first four problems; the second, the last four. The first would treat of perception in its general relations (a) to the environment, physical and bodily, and (b) to psychophysical preparation or predisposition. The last four groups may be classed together as treating of specific problems: (a) derangements of perception, (b) relation of perception to thought, (c) perception in animals, and (d) the development of perception in the individual and in the race.

3. *Methods of investigating perception.* We have seen that the problems of perception are varied and numerous, and that they correspond to different interests, different points of view, and different modes of systematic formulation. Now as we advance to the discussion of methods and means of solution we may reasonably expect a like variety. The means which have actually been used in the study of perception we have collected from the journals and the monographs, and we find that they may be arranged under the following six categories: (1) logical, (2) introspective, (3) psychophysical, (4) comparative, (5) genetic, and (6) behavioristic. The interpretations put upon these terms agree with those proposed by Ruckmich.[48] The first is a rational principle applied for the sake of interpretation; the second is 'method' taken in the narrower sense; the third, a mode of procedure employed under experimental methods; and the fourth, fifth, and sixth are, primarily, points of view.

i. The *logical method* is the term which I have used to include all those procedures whereby unanalyzed experiences have been brought together in the mass and by reflection interpreted. It is the sort of means which an investigator uses when he reasons out descriptions of mental experiences without subjecting them to experimental control or even to experimental identification. It is a general and uncontrolled

[48]Ruckmich, C. A., A schema of method, *Psychol. Rev.*, 1914, xxi, 401.

manner of investigation to which psychologists still resort. To illustrate the point, we may refer to Aaronson's[49] interpretation of the relation of perception to knowledge and action, wherein he contends without experimental verification that a man of the dullest type would show more knowledge than the most perfectly contrived mechanical being because he is able to comprehend the meaning of the perception and suitably to adapt himself thereto. But there is no hint of experimental control and no test of presuppositions. Again, an application of this same method is shown in Grünbaum's[50] analysis of the psychophysiological nature of visual impressions of movement in primitive man, where analogies are drawn between structure and mental event and between modern and primitive man. Nevertheless,—in spite of its limitations,—the logical method of interpretation and investigation finds a place in solving just such problems as the last mentioned, where experimental control is impossible. It finds further application, too, in the description and interpretation of conscious moments, which are common to a great mass of people, *e. g.*, the conception of an international war which brings the whole reading world into a single group. Here again, a direct survey by experiment would hardly be feasible. But in the problems of perception the logical method should occupy a subordinate place.

ii. *Introspection* is the one method peculiar to psychology alone. By it we mean the direct, controlled observation of mental phenomena for purposes of analysis and description. From these immediate observations the experimenter makes interpretations and correlations of fact. In practice, however, the introspective method is interpreted in two distinct ways: first and primarily, to analyze and describe mental processes; and secondly, to indicate and estimate meanings and relations, *i. e.*, to give information concerning objects and to comment upon the progress of events.

(a) The first application of the method is the one which has received the sanction of modern systematic psychologists, since every kind of mental event presumably lends itself to this means of investigation. There is—as its champions maintain—no single kind of psychical material to which introspection is limited, and therefore, facts gained by any other method may be substantiated by a direct inspection of mind. Titchener has defined and outlined a schema of the introspective method[51] in which he maintains that introspection includes "an attention from the standpoint of psychology, and a record in the terms and under the captions of psychology." He further proceeds to distinguish two forms of introspection, the direct and the indirect; the first being an immediate description of the processes, the second, a description made upon the basis of reproduced processes, or the memorial image. Titchener's account of introspection substantially agrees with G. E. Müller's critical exposition of the preceding year.[52]

[49]Aaronson, I., Perception, *J. of Philos., Psychol., Etc.*, 1914, xi, 37.

[50]Grünbaum, A., Ueber die psychophysiologische Natur des primitiven optischen Bewegungseindrucks, *Folio Neuro-biol.*, 1915, ix, 699.

[51]Titchener, E. B., The schema of introspection, *Am. J. of Psychol.*, 1912, xxiii, 491.

[52]Müller, G. E., Zur Analyse der Gedächtnisstätigkeit und des Vorstellungsverlaufes, *Zsch. f. Psychol. u. Physiol. d. Sinnesorgane*, 1911, Ergbd. v, 64. In describing the method, Müller says, "Von Selbstwahrnehmung rede ich überall da, wo in Beziehung auf einen psychischen Zustand durch unmittelbare Auffassung desselben oder durch Erinner-

(b) The term introspection, used as a description of meanings, as a designation of knowledge-about-an-object, or as running comment upon an experiment does not analyze in terms of process. By its use the observer reports fragmentary knowledge of objects and conditions. Take, for example, the problem of the relation of thought to perception investigated by Aveling, in which the observers were subjected to certain conditions which they reported as 'typical' or 'individual.' No attempt was further made to analyze the processes which carried this meaning. A few samples from the observations of Aveling's[53] observers will bring out the difference between facts gained through the informative method and the materials of introspection strictly taken. The mere description of the meaning is made evident by the following: "I did not see that as a type of a class. It was a letter-scale. The bars were yellow, the support black. I cannot draw it; for the meaning of the instruction came to me and troubled me. There was an inhibition. No word came to consciousness. I at once thought of Nardis' machine. He had one." . . "It was a pair of bluish nippers. No word came to consciousness. They were closed. I think I saw it as a picture and as type."

The 'informative' variant of the method, which principally records running comments upon the experiment, falls as far short of describing consciousness in terms of processes as does the related type just illustrated, the one which yields bits of knowledge or reflection. No interpretation can be made concerning the actual composition of perception from confessions of the following character. "I can't say much of the first stage. The picture rolls on, but doesn't take a final interpretation at first. I feel there is a preparation for a definite final something. I had confidence of something definite which would come up when the picture was gone. Then I saw other parts, and the previous interpretation was choked down by this new sensation, and so the other never appeared in full consciousness." . . . "it's an awful effort to look at one thing. It's easier to be passive than active."[54] Such reports do not so much describe objects as merely comment upon the attitude of the observer during the period of experimentation or upon the course of the experiment itself.

iii. *The psychophysical methods*[55] have played an important rôle since Fechner's time. They are peculiarly adapted to the study of relationships between stimulus and sensation. Since perception has its origin in the direct stimulation of receptor organs, all modes of procedure which may help to illuminate the relations obtaining between

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ung an denselben etwas konstatiert wird, . . . Wenn es sich um die Schilderung eines äusseren Gegenstandes handelt, kann die Beschreibung entweder auf Grund gegenwärtiger Wahrnehmung des Gegenstandes oder auf Grund der Erinnerung an eine oder mehrere frühere Wahrnehmungen des Gegenstandes erfolgen. Findet die Beschreibung auf Grund gegenwärtiger Wahrnehmung statt, so steht es stets so, dass die zur Schilderung gelangenden Eigenschaften oder Teile des Gegenstandes sukzessiv die Aufmerksamkeit besitzen und ihren Besonderheiten in allgemeinen angemessene, von sprechenden Worten begleitete Apperzeptionen (Erkennungen) erfahren."

[53] *Op. cit.*, 221.

[54] Smith, F., An experimental investigation of perception, *Brit. J. of Psychol.*, 1913-14, vi, 327, 333.

[55] For discussion see Titchener, E B., *Experimental Psychol.*, II. Pt. II, Introd., N. Y. 1905.

stimulus and the attributes of sensation may be given a place in the study of this topic. The psychophysical methods have most frequently been applied to perceptions in the visual, auditory, and cutaneous fields, but are widely applicable where quantitative results are sought. An illustration of a psychophysical mode of procedure would be such an experiment as the determination of the influence of accommodation and convergence upon the perceptions of depth,[56] wherein the amounts of accommodation and convergence may be accurately measured and correlated with the degree of depth perceived; or, the determination of the influence of expectation upon localization of sound by the number of errors made.[57]

All the methods so far discussed are those peculiar to the psychology of the human individual. The other three modes of procedure which have helped to solve problems of perception are the comparative, genetic, and behavioristic. All of them may be applied to organisms below man as well as to man himself.

iv. *The comparative method* is a mode of procedure peculiar to itself, namely that of inferring animal mind from human mind. One necessary step is a comparison of the animal and human forms in respect to structure, functions, and behavior. When an animal acts in a given manner under given conditions, the investigator constructs the animal mind on the basis of a comparison with human mind placed under similar circumstances, but with due allowances made for differences of structure, function, and manner of living. The literature upon animal psychology reveals many illustrations of this method. A representative instance is furnished by the article by Johnson already cited.[58] Johnson first determines the differences necessary in certain patterns to be perceived as discrete both by man and by the monkey and the chick. He then constructs the mind of the lower animals on the analogy of the human mind.

v. *The genetic method* may likewise be applied to animals. An instance of an investigation carried on to determine the phylogenetic relationship of various organisms is furnished by Hamilton.[59] By subjecting various beings, as men and children of various ages, monkeys, cats, dogs, and a horse, to the same problem under the same conditions, a comparison was attempted between the reactions of the same species at different ages, and between animals of different genera. This manner of approach is also applicable to problems dealing with the development of the individual. For example, the experiment of Judd and Cowling[60] referred to above, presents the problem of the genetic growth of perception in man with suggestions for a method for its solution.

An investigation of mind from the genetic point of view is advocated by Kirkpatrick, Yerkes, and Baldwin. According to Kirkpatrick the methods of genetic and comparative psychologists are similar. He believes that the student interested in mental growth must first know the structure and behavior of the simpler organisms and then,

[56]Baird, J. W., The influence of accommodation and convergence, etc., *Am. J. of Psychol.*, 1903, xiv, 150.

[57]Geissler, L. R., *op. cit.*

[58]Johnson, H. M., *op. cit.*

[59]Hamilton, G. V., A study of trial and error reactions in mammals, *J. of Animal Behav.*, 1911, i, 33.

[60]Judd, C. H. and Cowling, D. J., *op. cit.*

by inference, construct its mental life.[61] Yerkes,[62] likewise, implies the use of inference in the investigation of individual and racial mental development. Emphasis, however, is placed repeatedly upon the observation of organisms, especially upon the observation of behavior and its adaptive functions.

In Baldwin,[63] we find an entire program outlined and carried through. He assumes that mental growth runs parallel to the development of the nervous system. The task involves a determination of the amount of mental development at various levels in the individual. The suggested manner of approach is that of the dynamogenic method,[64] or an interpretation of the development of the mind by its reflection in movement.

vi. *The behavioristic method* does not attempt to describe mental phenomena as does the comparative method. In its extreme form it seeks only to describe movements and to refer them to antecedent stimuli. An illustration of this method is to be found in an experiment by Bingham,[65] wherein no interpretation of mental processes is attempted. Even in the milder forms of behaviorism, perception is scarcely a problem in itself, but only in so far as it is implied in the description and explanation of organic processes. And in the most uncompromising forms of this branch of ecological study, there is no place at all for the problems of perception.[66]

Thus we find that various paths of approach are available in connection with the problems of perception; though only one of them arrives at actual description in terms of process and form of integration. Our six methods fall into two natural groups. The first group, which includes the logical, introspective, and psychophysical forms, involves in various ways the individual whose mind is under investigation. The psychologist who makes use of the logical method bases his descriptions upon a reference, more or less explicit and exact, to facts taken from his own or from similar experiences; the psychologist who employs the psychophysical methods is dependent upon the judgments of the observer; while the introspectionist finds his facts of perception by immediate observation.

The second group, which includes the comparative, genetic, and behavioristic forms, is characterized by a primary dependence upon the observation of overt actions or of other organic activities. From this common starting-point, the three

[61] Kirkpatrick, E. A., *Genetic psychology*, N. Y., 1910, 3.

[62] Yerkes, R. M., *Introduction to Psychology*, N. Y., 1911, 212.

[63] Baldwin, J. M., *Mental development in the child and the race*, N. Y., 1895.

[64] *Ibid*, 43.

[65] Bingham, H. C., Size and form perception in Gallus domesticus, *J. of Animal Behav.*, 1913, iii, 65.

[66] Pillsbury (*op. cit.* 14), however, maintains that facts gained from the observation of behavior should be substantiated by introspection.

diverge in their several interpretations of behavior. The first emphasizes the comparison of minds of different forms, the second, the development of mind, and the third, the correlation of response with stimulus.

Chapter II

Experimental Investigations

A. An Analysis of Perceptual Complexes

Problem and method. The main purpose of these investigations has been to obtain a descriptive analysis of perception. In the first series of experiments the primary object was to study certain fairly simple perceptual formations, laying special emphasis in our description upon (1) the kinds of process involved, upon (2) the modes of their integration, and upon (3) the temporal sequence of the component members. For this purpose, twelve series composed of ten irregular inkblots[67] were used. There were five observers, C, Ra, Ru, S, and V.[68] The observer (O) was seated four feet from the exposure apparatus, a modified Whipple tachistoscope, which was employed throughout the experiments. Two seconds after a 'ready' signal, a card, bearing an irregular inkblot (about 3 cm. x 3 cm.) was exposed for .2 sec. The following instructions were given to O.

"Two seconds after a preparatory signal is given, a visual field will be exposed. After the exposure, an auditory distraction-stimulus will be sounded. At the signal, fixate and attend to the cross. After the exposure period, give (1) an introspective account of all mental processes occurring between the begmning of exposure and the distraction-stimulus, and (2) a verbal description of all objects perceived."

At each sitting, a series of ten cards was completed. The twelve series were repeated twice, wholly or partially, for each observer, once with .25 sec. and once with .5 sec. exposure. The time of exposure was standardized by using a

[67]These inkblots were similar to those used by G. V. Dearborn (A study of imaginations, *Am. J. of Psychol.*, 1897, ix, 183).

[68]The observers who served in these experiments were (in alphabetical order) a graduate student, Dr. Helen Clark (C); an advanced undergraduate, Miss Helen Davis (Da); and five instructors in the department, Dr. J. E. DeCamp (De), Dr. C. Rahn (Ra), Dr. C. A. Ruckmich (Ru), Dr. A. H. Sutherland (S), and Dr. T. F. Vance (V). The writer takes this opportunity to express her sincere appreciation of their services and especially to acknowledge her indebtedness to Professor Bentley for his constructive criticism and supervision throughout the investigation.

single 'standard' card, when timing the apparatus. After the distraction-stimulus, the introspections were recorded by the experimenter, who asked such questions only as were needed to clarify the reports. The O's were all given preliminary training on four series, similar to the main series, before the twelve main series were begun.

Results. From our introspective reports we find that, for the greater part, perceptual complexes are—under our conditions—composed of sensational and imaginal materials. A few representative introspections will illustrate the type of report and the critical analysis made of the experiences:

"First there was a complex of visual sensations, which meant nothing more than an inkblot of some form. The perception of this was not very clear. Then occurred a visual image of the inkblot, very weak, but persistent. After the image, there seemed to be a break in the direction of attention. During this time there was a great deal of eye strain, which meant an endeavor to clear up the meaning. The duration was intermittent and the intensity low. There were also some kinaesthetic processes from the throat, but they were very vague and brought no definite words." (S)

"The greyness values of the blot were very clear, but meant nothing but an outline of some sort. Then came a visual image of a picture of shoes. The spot then *meant* this, and the image was assimilated right into the visual complex. Then came some 'throat' kinaesthesis and visceral sensations, meaning an endeavor to clear up the meaning." (Ru)

Affective processes were very seldom noted, and then seemed to be of minor importance for the perception, since they were usually related to some individual component rather than to the complex taken as a whole. Of the sensational processes, the visual, by virtue of their direct initiation under stimulus, played an important rôle in the total pattern, making up about 26% of the total number of processes or homogeneous groups of processes reported for all exposures by all observers. But when we find further that processes indirectly evoked within the body, the organic and kinaesthetic sensations, compose 39% of the total number, those directly evoked seem to become of relatively less primary importance so far as the 'bulk' of the perception is concerned.

When the organic sensations occurred, they were always general, but with two possible variations: first, the 'thoracic' and 'abdominal' processes were closely integrated and not distinguishable, or secondly, they were not closely fused and either one or the other stood out emphatically from the total complex. These processes by themselves, however, form but a small part (3%) of the entire group for all observers.

Kinaesthesis, on the other hand, represents the largest per-

centage (36) of any particular class of mental phenomena reported. Both muscular and tendinous sensations were observed. The muscular changes involved may be classified with respect to localization; they were either of the general, diffuse, bodily type, or specially localized in some definite part of the body. The classes of 'muscular' sensations as given in the order of frequency of occurrence are: general (474), 'verbal' (348), ocular (178), head (72), chest and face (each 3), neck (2), and hand (1). The instances of tendinous strains are all very definitely localized in the eyes and head, with a frequency of 243.

Beside the sensational processes, both directly and indirectly evoked, introspection also reveals imaginal processes of various classes, visual, auditory, kinaesthetic, and tactual. All imaginal materials considered together form about a third (35%) of all processes; the visual alone, 27%; kinaesthetic, 7%; auditory and tactual each, .6%. From these proportions, it appears that visual imagery is of importance in visual perceptions. The distribution of the various processes in the different temporal phases for all observers is given in Table I, which is composed from 882 exposures of irregular inkblots, distributed among the five observers.

The perceptions of the 882 exposures represent 94 formations which differ among themselves as regards arrangement of processes and temporal course. Since there were 882 exposures, there were, of course, a like number of possibilities of formation. But with all these possibilities the fact that the whole number can be subsumed under 94 configurations implies that perceptions tend to conform to typical integrations. Thirteen 'typical' patterns, those with a frequency of eighteen or more, are given in Table II, where VS and VI stand for groups of visual sensations and visual images, and the subscripts F and D for the kind of meaning conveyed (*cf.* Table I and p. 548). The sign '>" stands between successive phases and the oblique lines separate parallel processes. The total number of these thirteen configurations is 460, or more than half. In Table II they have been grouped according to similarity of process, of mode of integration, and of function.

1. Group I represents integrations of visual sensations (VS), kinaesthesis, and visual imagery (VI). There is but slight variation from formation to formation, the chief difference being one of temporal sequence. General kinaesthesis stands out as one of the essential factors in each pattern. In the last three, the diffuse, bodily kinaesthesis is supplemented

TABLE I

Type of process	SENSATIONAL												
Class	VISUAL							ORGANIC					
Subclass													
Meaning of complex[1]	F	D				A	S						
Temporal phases	1	1	2	3	4	1	2	1	2	3	4	5	
Total number of records of all observers	835	44	27	48	1	3	2	5	53	46	26	2	
Total number of uses for each meaning	835	120				3	2						
Percentages	87	12.5				3	2						
Total of subclasses													
Total of class	960							132					
Percentages	25.8							3					

[1] The letters F (figurational), D (depictive), A (abstract), and S (symbolic), distinguish the perceptions according to the kind of meaning or reference which they bear (cf., p. 548, inf.).

TABLE 1—*Continued*

Type of process	SENSATIONAL—*Continued*																					
Class	KINAESTHETIC																					
Subclass	MUSCULAR																			STRAIN		
	General					Chest	Hand	Head		Neck	Face	Ocular			Verbal				Eyes and Head			
Meaning of complex																						
Temporal phases	1	2	3	4	5	2	5	2	3	3	2	1	2	3	1	2	3	4	1	2	3	4
Tot. No. of Rec. of all Obs.	15	300	56	43	60	3	1	70	2	2	3	37	116	25	13	202	127	6	13	150	1	79
Tot. No. uses for each meaning																						
Percentages																						
Total of subclass	474					3	1	72		2	3	178			348				243			
Total of class	1324																					
Percentages	36																					

TABLE I—*Concluded*

Type of Process	IMAGINAL																													
Class	VISUAL																AUDITORY			KINAESTHETIC									TACTUAL		
Subclass																				General		Verbal		Auditory-Verbal						
Meaning of complex[1]	F				D				A		S																			
Temporal phases	2	3	4	1	2	3	4		2	3	2	3		2	3	4				3		3		1	2	3	4		2	3	4
Tot. No. of Rec. of all Obs	205	290	15	2	113	287	44		7	11	11	8		3	18	1				3		3		24	124	88	17		3	18	1
Tot. No. of uses for each meaning	510			446					18		19																			
Percentages	51			45					2		2																			
Total of subclasses																				3		3		253						
Total of class	993																22			259								22		
P rcentages	27																.6			7								.6		

[1] The letters F (figurational), D (depictive), A (abstract), and S (symbolic), distinguish the perceptions according to the kind of meaning or reference which they bear (cf. p. 548, inf.)

TABLE II

Group	ORGANIZATION	Frequency	Total for group	Percentage
I	VS_r >General Kinaesthesis >VI_r	75		
	VS_r >General Kinaesthesis >VI_b	68		
	VS_r >Strain Sensations >VI_r >General Kinaesthesis	24		
	VS_r >Ocular Kinaesthesis >Kinaesthesis, General and Verbal >VI_r >VI_b	18		
	VS_r >Strain Sensations >$VI_r VI_b$ >Verbal Kinaesthesis >Strain Sensations >General Kinaesthesis	79	264	58
II	VS_r >Auditory-Verbal Images	28		
	VS_r >Auditory-Verbal Images >VI_r	23		
	VS_r >$VI_r VI_b$ >Auditory-Verbal Images	22		
	VS_r >$VI_r \begin{Bmatrix} VI_b \\ VI_b \\ VI_b \end{Bmatrix}$ / Auditory-Verbal Images	20	93	20
III	VS_r >Kinaesthesis >VS_b (Head, Eyes, General, Verbal)	46	46	10
IV	VS_r >VI_r	20		
	VS_r >VI_r >VI_b	18	38	8
V	VS_r >VS_b >General Kinaesthesis (Empathy)	19	19	4
	Total		460	100

by special, localized kinaesthesis, such as ocular and verbal. The visual imagery involved differs as to cognitive elaboration. It may be simply the sustained meaning carried over from the corresponding sensational phase and representing a 'nonsense' figure ('figurational') or it may be imagery with derived and extended meaning depicting some definite 'sense' object ('depictive').

2. Group II represents formations of visual sensations and visual and auditory-verbal imagery. The greatest difference among the four patterns is one of complexity with respect to the number of processes; the second may be considered as a greater elaboration of the first, in that the second terminated with a visual reproduction of the figure, which the first perception lacked. The remaining two formations are modifications of the second in respect to temporal sequence.

3. Group III is composed of but one type of integration. It is distinctively set off from the other groups by the fact that the object itself—as carried by visual sensations—changes from being apprehended as a mere irregular figure to one possessing a high degree of meaning.

4. Group IV is characterized by its absence of kinaesthetic and organic processes. Introspection revealed nothing but visual materials, sensational and imaginal. The second formation differs from the first in degree of meaning, the first never acquiring any more significance than that of an irregular, black figure. The temporal sequence is identical, with the exception that the second expanded into a third phase, in which derived meaning appeared attached to visual imagery.

5. Group V bears a strong resemblance to Group III with respect both to composition and to the function of some of the component processes. But there are also wide differences between the two groups as regards, first, the function of other processes and, secondly, the temporal course of the perception. First, as to similarities, the complexes of both groups are composed of visual and kinaesthetic sensations. Furthermore, the sensations of both groups, which were directly evoked, bear not only the meagre meaning of an irregular figure, but also acquire other significance. As to differences, first, in regard to function, the kinaesthetic factors serve two distinct purposes, that of effort or intent to seek meaning in the formations of Group III, and that of empathic interpretation in those of Group V. Secondly, there is a variation in temporal sequence. The visual processes bearing the derived meaning came after the kinaesthesis (effort) in the combinations of Group III, but accompanied the empathic kinaesthesis in those of Group V.

The groupings of these various perceptual formations may be determined not only upon the basis of similarity of combinations of processes by all observers, but also upon the basis of typical integrative patterns for individuals. Group I is characteristic of all observers (C, 5%; Ra, 20%; Ru, 50%; S, 25%; V, 6%); Group IV, of three, Ru, (6%), S (6%), and V (4%); Group V of three, C (10%), Ra (27%), and S (8%); Group II, of two, C (11%) and V (24%); Group III, of one, S (33%). We may further say that the type of perceptual pattern included in Group I is especially characteristic of Ru; that of Group II, of V; of Group III, of S; of Group V, of Ra; while observer C displays a high frequency in both Groups II and V.

If the integrations should be combined with respect to functional properties, the first two groups would be closely related. While the processes of all but the first phase differ widely, first as to type (those of the first group being sensational, those of the second imaginal), and secondly, as to localization (those of the first being general, those of the second, special), nevertheless, the processes serve similar functions within the perceptions. Both the kinaesthetic sensations and the auditory-verbal images perform the function either of *bearing meaning* or of self-instruction to *seek meaning* in the figure. The difference in process represents merely individual variations in interpretation or significance.

An examination of Table II reveals the following facts:

1. Visual sensations alone, for the greater part, compose the first phase of the perception.
2. Kinaesthesis, general and special, is an important component within most perceptual complexes and usually occurs in the second phase.
3. With very few exceptions, imagery, especially visual, occurs in every perception, but its appearance is for the greater part, comparatively late in the temporal course.

From Table I we see that introspection revealed seventeen different kinds of process within the perceptual complexes. Further investigation discloses the fact that these processes were distributed over no less than five temporal phases within the perceptions. Table III represents the distribution of the various processes in all the 882 perceptions with respect to kind and function, in the five temporal phases. The processes are arranged in each phase according to their order of frequency, from the greatest to the least.

Thus, in the first temporal phase of the perception, visual sensations, bearing the mere apprehension of the black figure, were the most frequent (835); the visual complex which carried a depictive significance, second in frequency (44); and so on. But parallel processes in the various phases are

TABLE III
TEMPORAL PHASES

Order	1	2	3	4	5
1	VS_V	General Kinaesthesis	VI_V	Strain Sensations	General Kinaesthesis
2	VS_D	VI_V	VI_D	VI_D	Organic Sensations
3	Ocular Kinaesthesis	Verbal Kinaesthesis	Verbal Kinaesthesis	General Kinaesthesis	Hand Kinaesthesis
4	Auditory-Verbal I agery	Strain Sensations	Auditory-Verbal Imagery	Organic Sensations	
5	General Kinaesthesis	Auditory-Verbal Imagery	General Kinaesthesis	Auditory-Verbal Imagery	
6	Verbal Kinaesthesis Strain Sensations	Ocular Kinaesthesis	VS_D	VI_V	
7	Organic Sensations	VI_D	Organic Sensations	Verbal Kinaesthesis VS_D	
8	VS_A	Head Kinaesthesis	Ocular Kinaesthesis	Auditory Imagery Tactual Imagery	
9	VI_D	Organic Sensations	Auditory Imagery Tactual Imagerv		
10		VS_D	VI_A		
11		VI_S	VI_S		
12		VI_A	General Kinaesthetic Imagery Verbal Kinaesthetic Imagery		
13		Facial Kinaesthesis Chest Kinaesthesis Auditory Imagery Tactual Imagery	Head Kinaesthesis Neck Kinaesthesis		
14		VS_S	Strain Sensations		

not to be interpreted as of approximately equal frequency; *e. g.*, the occurrences of general kinaesthesis (300) in the second phases are not so numerous as those of VS_F, in the first. The table simply indicates the relative importance of each kind of mental phenomenon in each temporal division of the total complex. While bodily kinaesthesis occurs in each phase, it may, nevertheless, be said to be most characteristic of the second, *i. e.*, if it appears anywhere within a perceptual integration, it is more apt to be subsequent to the processes directly evoked. Table III further shows that the accessory processes in every phase but the first are of much more significance to the meaning of the perception than the concomitant, directly initiated processes. For example, while the visual sensations may in the second, third, and even the fourth phase, possess significance other than merely that of a black area on white, nevertheless various other complexes have precedence in frequency. Of course, with other materials, the perceptual value of the first phase might be greatly emphasized.

Perceptions, then, which arise from the observation of inkblots, are composed of three fundamentally different kinds of processes; (1) those directly evoked, (2) those which are related to organic movement, and (3) imaginal materials derived from various sources. These have all been shown to be of primary importance to the perception, each discharging its own peculiar service or supplementing that of other processes.

In this investigation, the visual complexes were found to perform four various functions. First, the object was apprehended, either directly or indirectly, as being merely a black area on white.

"The visual complex simply meant an irregular figure of some sort." (Ru)

This type of meaning we shall designate as *figurational* (VS_F or VI_F). Secondly, the same complexes were involved in the ascription of other meaning, in depicting the figure as some particular object (VS_D or VI_D), *depictive* function.

"The figure meant a bull-moose, horns and all very definite." (S)

Thirdly, the visual processes did not depict a particular object such as a particular hill, tree, or house, but they bore the meaning of a concept, as of centipede or of quadruped or of triangularity.

"In the perception, the object immediately became a general representation of such an animal as a centipede." (S)

We have designated this function as *abstract* (VS_A and

VIA). Fourthly, the figure might be apprehended, not as some definite and particular object, but as a representation of an object, as a symbol (VSs and VIs), *symbolic function*.

"The visual and auditory imagery carried the meaning that this was a symbolic representation of a waterfall." (Ru).

Reference to Tables I and II will make it clear that in the perception of figures which possess no, or only slight meaning the visual processes more frequently display figurational and depictive functions than abstract and symbolic. While the figurational and depictive functions, taken together, occur with the same frequency in the sensational (955) as in the imaginal (956) processes, yet there is a decided difference when considered separately. As many as 835 of the visual sensation-groups were figurational and but 120 depictive, while in the case of imagery, 510 were figurational and 446 depictive, thus indicating that imagery is here of more importance than sensations in giving derived significance.

Again, in the case of abstract and symbolic functions, there is a greater frequency in imagery than in sensations. Thus, the primary function of the directly initiated processes becomes one of bare apprehension of object, while that of imaginal materials is to elaborate upon the meaning.

Whatever primary meaning the perception possessed usually appeared with the visual complexes. In this sense the perceptions are correctly called 'visual.' The kinaesthetic and organic processes, sensational and imaginal, did little at first to add to or to modify it. Their chief function in the first phase was (1) to bear effort or intent to find-significance-in-the-figure, or (2) to question the fitness of meaning ascribed by other processes. Thus, they were accessory to the visual complexes rather than directly assimilated to them. Group V of Table II, however, is an exception to this kind of function. In this mode of integration the empathic kinaesthesis substantiated the meaning attached to the visual sensations, thus actually displaying a depictive function, although the interpretative function is still evident.

The auditory and tactual imagery perform a service similar to that of the organic and kinaesthetic processes, *i. e.*, they carry self-instructions either to seek meaning in the figure or to determine the appropriateness of significance. They primarily represent individual differences in the observers in the interpretation of the figures. Auditory and auditory-verbal imagery in the cases of C and V and tactual imagery in the case of Ra discharge the same office as kinaesthetic

processes do for other observers and frequently also for these same observers.

Summarizing our experimental results thus far presented, we may say that perceptions have a tendency toward certain integral formations which possess peculiarities due to individual differences but which, nevertheless, conform in general to common patterns. Within these configurations, the various processes follow a temporal course quite definitely determined; the directly evoked sensations showing a marked precedence over all others in the first phase, the indirectly initiated sensational complexes composing the greater part of the second, and imaginal processes holding predominance in the third. Again, the various processes which compose the perception display some specificity of function; the visual processes bear the primary meaning, while those connected with organic movement together with the imaginal components both interpret and extend whatever significance the figure may derive and enforce the intent to enrich the perceptual meaning.

B. The Elaboration of Perceptual Meaning.

Problem and method. Typical integrations having been established for perceptions of figures with very slight or nominal significance, it became the primary task of this immediate part of the investigation to determine whether an essential change occurs in perception when material with a slightly higher degree of significance is used. For this purpose, we made use of hieroglyphics and cubists' drawings. A series of 50 cards was made, bearing objects which suggested various degrees of meaning. The following illustrations are typical of the series.

These cards were exposed as the ink blots were for ½ sec. to the observers, C, Ra, and Ru. The instructions were as follows:

"Two seconds after a 'ready' signal, a figure will be briefly exposed. A distraction will be given at the end of two seconds. Upon distraction, report at once whether the figure is wholly devoid of significance. Then give full introspections."

Results. No difference in composition was discovered between the perception of inkblots with minimal meaning and the perception of figures possessing a greater degree of significance.

The complexes revealed types of integration similar to those of the first set. But, although there is no difference on the

side of composition, there is a marked change in the function of the different processes. Whereas, in the perceptions reported under the first experiment, many processes bore the general function of seeking and interpreting meaning, the same processes serve other purposes as well when the object becomes more 'meaningful.' In this series of investigations we have distinguished three kinds, interpretative, appreciative, and orientating.

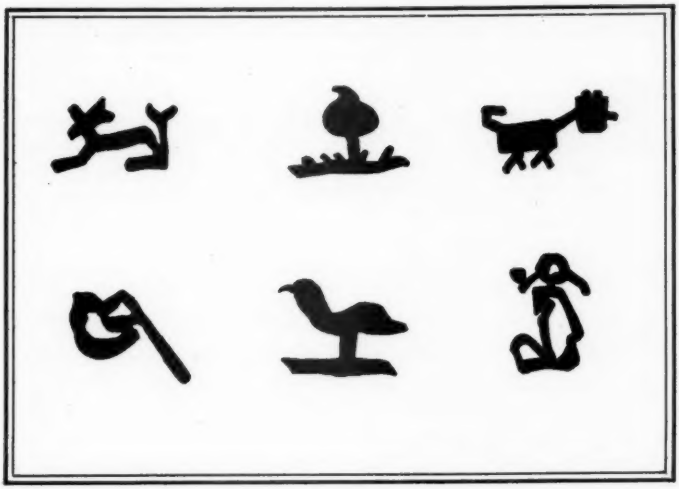


FIG. 1

The interpretative function is of the same type as we found prevalent in the perceptions of the first experiment. It is the effort or intent on the part of the observer to read meaning into the object. The following excerpts will illustrate its application as related to various types and classes of mental phenomena:

"I felt myself (general empathic kinaesthesis) standing erect and rigid, and then the meaning 'grass' came." (C)

"There was a very clear auditory image of the word 'bowl' and with it a general kinaesthetic set which meant the realization that the object was not like a bowl. Kinaesthesis of the hands and tactual imagery gave 'roundness' to the top." (C)

"There was much organic disturbance, which meant that the figure was complex, that it was a problem which I must solve." (Ru)

"Visual images assimilated with visual sensations gave the meaning of solidity." (Ra)

These illustrations not only indicate a similarity to the interpretative function of the processes in Experiment 1, but also a difference. In Experiment 1 we found that the interpretation was of the desiring, seeking, searching type without any satisfactory fulfillment, *i. e.,* if derived meanings did occur as a result of the search, they were usually rejected or at least not wholly accepted. In Experiment 2 we find this same intent and desire to derive meaning but with a difference. In the first, the effort is of the kind involved in 'puzzle' consciousness; in the second, it is accompanied by satisfactory realization.

Both sensational and imaginal components commonly functionate as explorers for meaning in the object. The sensations which serve in this manner have both a limited (visual) and a general (organic and kinaesthetic) origin. In the case of imagery, the materials are drawn from various sources, specific (as visual, auditory, and olfactory) and general (as tactual and kinaesthetic). The *interpretative* function, then, is not peculiar to a particular class of mental processes, although effort itself is directly connected with kinaesthesis.

The second function we have called the *appreciative* function, a term employed to designate the service of a process or complex of processes when the figure is valued, *i. e.,* where it gives rise to pleasure, enjoyment, or aesthetic sentiments. Examples follow.

"There was a general, kinaesthetic and organic complex, meaning amusement because the dog was so fantastic and so incongruous." (C)

"There were numerous visual images of scalps and skins and of tortoise-shell combs of variegated colors. With this was a pleasant organic complex. The total complex signified the richness of meaning of the object." (Ru).

"There was a background of visual imagery, associations from the history of man, carrying an appreciation of the feeling of unity with man." (Ra).

As regards the interpretative function, we found that any kind of mental process might fill such an office, whereas only the indirectly evoked sensations (organic and kinaesthetic) and imaginal processes carry the appreciative function and, moreover, that the imaginal processes which here functionate as appreciation are limited to the two classes, visual and kinaesthetic-verbal. This would seem to indicate either (1) that the meaning of these perceptions was not yet complex or

evident enough to involve many processes in appreciation, but still demanded much interpretation, or (2) that fewer kinds of process actually perform this valuating or estimating service.

The *orientating* function is a third kind of performance distinct from either the interpretative or the appreciative. There is no effort or attempt involved to attach purport to the object, nor is there any valuation of such meaning as may be present, but the processes functionate in placing or localizing in time or space the object with reference either to the observer or to other objects.

"There were some organic processes in the background, allied with kinaesthetic processes which gave the object position." (Ru)

"There was confused visual imagery referring to sketching classes where they had drawings of friezes, of Egyptian designs, and of Greek and Roman figures." (C)

"There came an auditory image of the word 'curlique' which was accompanied by auditory imagery referring it back to other diagrams meaning the same thing." (Ru)

"This reference to books on archeology came in terms of visual imagery of pictures and kinaesthetic-tactual imagery of the feel of the page with print and pictures." (Ra)

The orientating function, then, is characteristic of organic and kinaesthetic sensations and of imaginal processes from various sources. Of the images derived from definite sources, we find visual and auditory; of those with a diffuse origin, tactual and kinaesthetic.

Although three kinds of functions may be assigned to the various processes, nevertheless, as far as our results indicate, we cannot say that all are of equal importance in giving meaning to the perception. In Table IV the total number of processes has been recorded under each function with respect to the capacity of each for carrying these three kinds of significance. The interpretative, appreciative, and orientating functions are indicated by I, A, and O, respectively. The symbols + and — indicate whether or not processes discharging particular functions, added to the significance of the perceptions.—a significance, which had already been derived, *e. g.*, the meaning 'horn' is already attached to a visual complex, when an auditory image of the word 'horn' subsequently occurs. The latter supplies nothing new to the context and is therefore set down as —.

TABLE IV

Observers		No. of + and — Processes								Total No. of Processes			
		I		A		O		A and O		I	A	O	A and O
		+	—	+	—	+	—	+	—				
C	Totals.....	152	27	21	0	42	17	63	17	179	21	59	80
Ra		77	18	8	1	15	9	23	10	95	9	24	33
Ru		96	66	35	1	57	35	92	36	162	36	92	128
C	Percentages....	59	10	8	0	16	7	24	7	69	8	23	31
Ra		60	14	6	0.8	12	7	18	7.8	74	6.8	19	25.8
Ru		33	23	12	0.3	20	12	32	12.3	56	12.3	32	44.3
	Grand totals...	325	111	64	2	114	61	178	63	436	66	175	241
	Percentages....	48	16	9	0.3	17	9	26	9.3	64	9.3	26	35.3

From an inspection of this Table we may conclude as follows:—

1. In perceptions possessing a moderate degree of meaning, processes which serve as 'interpretation' are approximately twice as frequent (436) as processes which valuate and localize (241) the object. This observation points to the fact that the meaning was not so evident but that most of the components in the perceptual process stood for effort or intent to attach significance to the figure.

2. Every kind of component in the perception shows a greater tendency to be positive rather than negative to the meaning, *i. e.*, in every instance, the processes which contributed to the meaning greatly outnumber those which failed to enlarge the significance. All of the 'appreciative' processes, with two exceptions, enriched meaning. The phenomena which localized the object, however, made no contribution to the meaning about half as frequently as they added thereto. Although we have said that processes add or fail to add meaning, we cannot say how much each process contributes to the significance of each perception. For example,—to take a typical illustration,—we perceive an irregular figure which assumes the derived meaning of 'cannon' by virtue of the visual sensations themselves. Then appears a visual image of this spot, still possessing the meaning 'cannon.' In this instance, it is evident that the sensations were of much more importance to the meaning than the images, and that although there were two types of process we cannot say that each contributed one-half the meaning. Meaning itself is 'richer,' 'poorer,' 'more or less elaborated;' but it is not divisible into fractional parts.

3. After the interpretative processes have run their course, other processes have a greater tendency to serve in placing the object in space and time than for appreciation. There are approximately three times as many 'O' as 'A' processes.

4. From the general results of Table IV, there seems to be a temporal evolution of the various functions of process from perceptions with minimal meaning to those with considerable meaning. When meaning is minimal, the processes serve for bearing and interpreting it. Then as meaning becomes more elaborate, the processes acquire other functions, first that of localization, and secondly that of appreciation.

Table IV also reveals some individual differences with respect to the functional aspect of mental processes.

1. The 'I' processes vary from 56% for Ru to 74% for Ra. (This difference should be considered in connection with Table V, below.)

2. Ru shows a higher ratio between his 'O' and 'A' processes and his 'I' processes than either C or Ra.

3. There are also marked differences with respect to the relation of the processes to the meaning. Ru has approximately as many 'A' and 'O' as 'I' processes which add to the meaning, while C and Ra show a predominance of positive 'I' processes. In Ru's perceptions, also the 'I,' 'A,' and 'O' processes which do not add to the meaning have a lower ratio to those that are positive than is true in the case either of C or of Ra.

We have seen that there is a tendency for the 'A' and 'O' processes to increase in frequency as meaning becomes more elaborate. In our next table (V) this relationship of process to degree of meaning becomes more clearly apparent. Here the meaning of the object has been designated as 'none,' if it possessed no significance other than that of a black area on white. It will be recalled that this series was purposely so made as to bear varying degrees of suggestion. 'Slight' indicates that there was present a low degree of meaning, which was usually indicated by hesitation on the part of the observer to accept it, or by lack of details, or by the predominant function of all the processes involved. 'Considerable' indicates that the object was rich in detail and setting.

In the case of 'no' meaning the results quoted in Table V show that but few processes with the orientating function occurred and none of the appreciative type. But in perceptions, which possess 'slight' meaning, there is a greater frequency both of the 'A' and 'O' kinds of process with a greater prevalence of the 'O' type. The same is true of complexes listed under the third degree of meaning. This further substantiates the statement made above that as meaning develops more and more the accessory components of the perception acquire new functions, namely, the orientating and the appreciative. The processes discharging these services also vary directly in frequency with the significance. Table V further shows that, if judged by frequency, the same classes of process assume the orientating function before the appreciative, *i. e.*, in the instances of 'no' meaning, there were but few 'O' processes, and no 'A' processes, while in the other instances, the 'O' processes always exceed the 'A's'. This fact illuminates the reason for Ru's displaying such a high frequency of 'A' and 'O' processes (Table IV). From Table V, we see that Ru reported no perception under the 'none' degree of meaning.

These facts accord with those of the first series of experiments, where, with the exception of the integrations listed under Group V of Table II, all accessory processes presented

TABLE V

Observers		Meaning											
		None				Slight				Considerable			
		I	A	O	A and O	I	A	O	A and O	I	A	O	A and O
C	Totals.....	12	0	2	2	58	5	18	23	109	16	39	55
Ra		7	0	3	3	26	2	7	9	62	7	14	21
Ru		0	0	0	0	48	8	27	35	114	28	65	93
C	Percentages	5	0	8	8	22	2	7	9	42	6	15	21
Rn		5	0	2	2	20	2	5	7	49	5	11	16
Ru		0	0	0	0	17	3	9	12	39	10	22	32
	Grand totals	19	0	5	5	132	15	52	67	285	51	118	169
	Percentages	3	0	.7	.7	19	2	8	10	41	8	18	26

clearly the interpretative function, since the figures used in those experiments possessed just as little meaning as possible. In the case of perceptions which involved empathic kinaesthesis, which was mostly interpretative, but with a suggestion of the localizing function, the objects were probably of the same degree of meaning for the various observers as those judged as having "no" meaning in the second series of 'object' cards.

The following general conclusions may be drawn from the results of Experiment 2:

1. The accessory processes, kinaesthetic and organic sensations and various imaginal components, acquire functions other than the interpretative, as meaning grows more elaborate. In this experiment these new services have been found to be appreciative and orientating.
2. The accessory processes which perform the appreciative and orientating functions increase in frequency directly with the degree of meaning.
3. The various functions of mental processes appear in a definite order, in perceptions of varying degrees of meaning; (1) interpretative, (2) orientating, and (3) appreciative.

C. Relation of Attention to Perception.

Up to this point our experimental results have shown us, first, that perceptions fall into typical integrations, secondly, that perceptions present various degrees of cognitive and appreciate elaboration, and thirdly, that the elaboration of significance is relatively independent of the particular kind of mental processes involved. But our analytic problem is not yet complete. We must not neglect the state and the configuration of the total bit of mind in which the perceptual complex is embedded. This is the problem of the relation of attention to perception. We approach it by taking an inventory of all the processes, at their several degrees of clearness, which lie both within and without the particular constellation which we have undertaken to study.

1. *Preliminary series.*

Problem and method. In order to train our subjects to observe these degrees of clearness or vividness, two series of preliminary experiments with distraction were performed. In the first a series of nonsense-syllables was exposed, approximately one each second, which was to be memorized by the observer. Some time during the learning-period a distraction was offered by drawing a pattern upon the back of O's left hand with the blunt end of a pen shaft. At a signal "now,"

O introspected for that instant, estimating the various processes according to nine degrees[69] of clearness.

The second series of experiments consisted of a double task. O was given one of the cancellation test-sheets and asked to mark all 'a's'. While he was thus engaged, simple arithmetical sums and multiplications were orally given and their solution demanded. At a signal 'now' full introspections were reported with respect to the clearness of the processes, which were present just at the signal 'now.' The experimenter in both series always attempted to give the signal 'now' while the observers were distracted either by the pattern or by the computation.

The instructions for the first series, where C, De, Ra, and Ru observed, read as follows:

"A 'ready' signal will be given. Two seconds later, the first of a series of nonsense-syllables will be exposed. Learn the series. During the learning-period, a distraction will be given by drawing a pattern on the back of your hand. At a signal 'now,' give an introspective account of the degrees of clearness of all processes, present at the signal 'now.' The degrees of clearness are to be judged in the following terms:

maximally clear	1
very clear	2
clear	3
fairly clear	4
fair	5
fairly vague	6
vague	7
very vague	8
obscure	9"

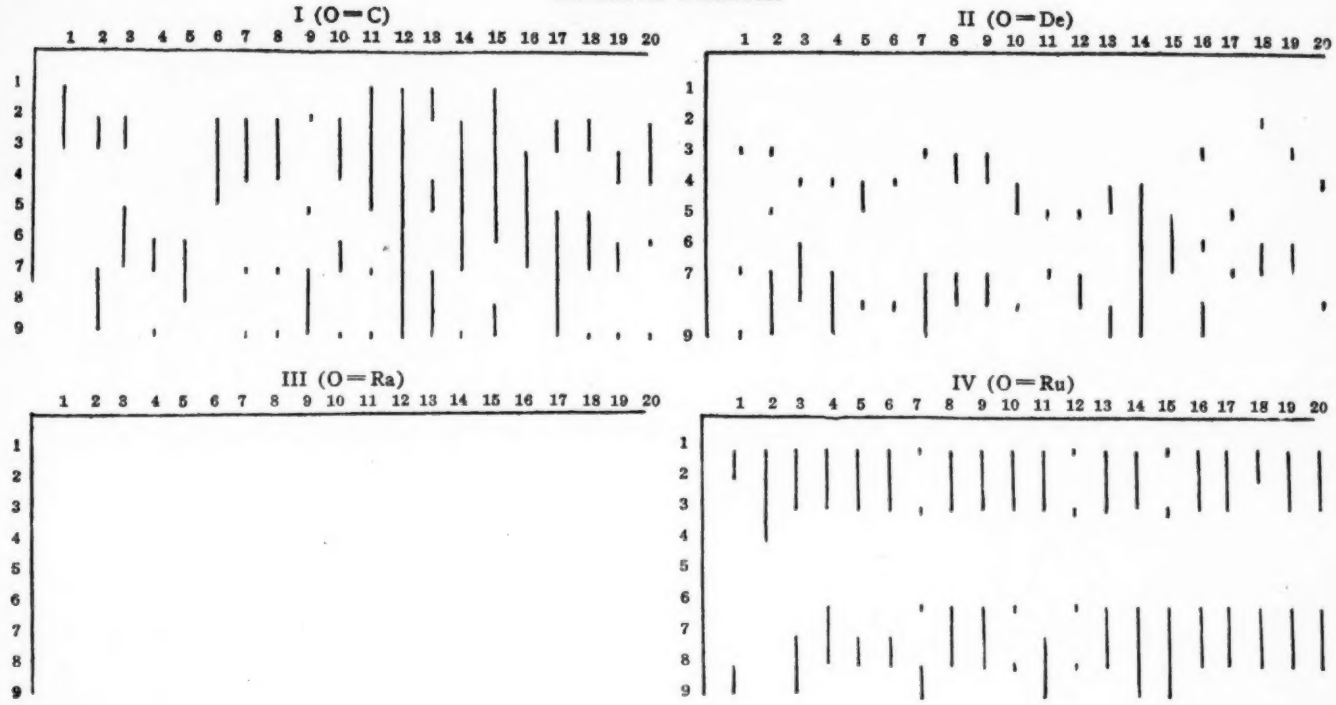
Instructions for the second series were:

"A 'ready' signal will be given. Two seconds later a signal 'start,' at which begin crossing out the "a's" on the sheet before you. During this process, simple arithmetical additions and multiplications will be given for about two seconds. At a signal 'now,' give an introspective account of the degrees of clearness of all the processes present just at the signal 'now.' The degrees of clearness are to be judged in the following terms; [the same 9 degrees were used as for the first series]."

Results. The two preliminary series of experiments resulted not only in training the O's in the use of the degrees of clearness, but also determined the type of consciousness of each observer, whether it was of the foreground-background type or multilevel. Graphs I-IV, showing the results for nonsense-syllables, illustrate individual differences.

[69] We employed the same 9 values for determining the degrees of attention as were used by Geissler, (The measurement of attention, *Am. J. of Psychol.*, 1909, xx, 502) and Dallenbach, (*ibid.*, 1913, xxiv, 468).

DEGREES OF CLEARNESS



In the graphs the trials are ordered on the abscissae, the degrees of clearness on the ordinates. Adjoining degrees are connected by solid vertical lines.

The diagrams then suggest that C and Ra and possibly also De, represent multilevel types of mind. The data for the double task series indicate results similar to those for the first series. Both are included in Table VI. The symbols 'N-S' and 'A' are employed to represent the nonsense-syllables and the cancellation sheet, respectively. It may be said in general that the observers exhibit a similar distribution of processes among the nine degrees of clearness with the exception of Ru, whose two-level division reduces the numbers for the medium and the very lowest degrees. And again, when Ru's estimations of vividness are divided into three large groups (for the sake of inspection), there is practically an equal distribution for each group. Ra, while he grouped most processes in the middle level for the 'N-S' series, nevertheless exhibits a greater frequency among the maximally clear than among the obscure processes. In his 'A' series, very clear processes are more frequent than those which are moderately clear, with still fewer obscure components. The general tendency for all observers seems to indicate that most factors within the perceptual complexes are moderately clear, fewer are obscure, and a still smaller number maximally clear.

2. *Main series.*

Problem and Method. The primary task of this investigation was to estimate the bearing of clearness upon perception. To this end, the original series of inkblots (see Experiment 1) was again used. As before, the observer gave full introspective reports concerning the perception, but, in addition, the clearness of each process was given on the scale of 1-9 according to the method employed with nonsense-syllables and the literal tests of our preliminaries.

The instructions read:

"Signal, exposure and distraction-stimulus will be given as before. During the whole period of observation take the perception quite passively; do not force an 'object.' Give full introspections, indicating perceptions and other meanings in parallel wth the description of processes. The introspections should include (a) analysis of complexes, (b) the sequence and order of groups, and (c) the area of maximal clearness. The degrees of clearness are to be judged in the following terms: [See instructions for preliminary series]."

The time of exposure was ½ sec., but introspection covered a period of 2 sec. C, De, Ra, and Ru observed.

TABLE VI

Clearness values	9 Degrees														3 Degrees											
	C				De				Ra				Ru				C				De				Ra			
	N-S		A		N-S		A		N-S		A		N-S		A		N-S		A		N-S		A		N-S		A	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
1	5	3	1	.4	0	0	0	0	15	17	17	30	30	18	18	14	23	18	18	9	10	6	0	0	34	40	27	47	55	32	38	30
2	18	14	17	8	10	6	0	0	19	22	10	18	25	15	20	16																
3	18	14	28	13	31	19	9	7	14	16	6	11	28	16	19	15																
4	16	12	37	17	20	12	35	26	10	12	4	7	2	1	0	0	62	48	118	55	98	61	78	58	38	44	21	37	56	33	53	42
5	14	11	27	13	23	14	22	16	8	9	8	14	2	1	14	11																
6	14	11	26	12	24	15	12	9	6	7	3	5	24	14	20	16																
7	19	15	23	10.6	27	17	21	16	10	12	3	5	22	13	17	13																
8	7	5	27	13	19	12	29	22	3	4	2	3	30	18	19	15	45	34	77	36	54	33	56	42	14	16	9	16	59	35	36	28
9	19	15	27	13	8	5	6	4	1	1	4	7	7	4	0	0																

TABLE VII (O = C)

TABLE VII (O = C)

Clearness values	1			2			3			4			5			6			7			8			9			All values			%			Proc. in 3 phases	%	Type of Proc.	%	Class of Proc.	%
Phases	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3						
Processes																																							
Visual																																							
Sensations	4			21	11		27	10		20	6	1	4	4		5	2		4			1		1	2			88	33	2	16	6	.4	123	22	123	22	207	37.3
Images																																							
Spot						1				1	1		1			8	1		7	3		1	5	5		2	7	1	24	18	.2	4	3	43	8	84	15			
Associations						1				3			2	2		2	6		6	9		1	1	5		3		1	17	23	.2	3	4	41	7					
Auditory images					1	3		8	10		7	5		7	1		7	2	2	3	1		5	3		1		2	39	25	.4	7	5	66	12	66	12	66	12
Cutaneous images																																				2	.4	2	.4
Pain																								2						2		.4	2	.4				
Organic sensations														1		1						1	1	3		2	2	2	4	5	.4	.7	.9	11	2	11	2	11	2
Kinaesthesis																																						268	48.3
Sensations																																				231	42		
Muscular:																																							
General				2					3	3				6	3	9	6	1	27	10	3	22	18	13	18	18	9	81	58	32	15	10	6	171	31				
Legs																1												1			2			1	.2				
Arms										1		1				1	2		4	5	1	1	6	1	2	1	2	9	14	5	1	2	.9	28	5				
Face												1			1									3						5			.9	5	.9				
Eye																							1		1			1	1		2	.2		2	.4				
Throat																			1	2		1		2				2	2	2	.4	.4	.4	6	1				
Strain:																																							
Neck				1								1			1	1		1	2				1					4	1	2	.7	.2	.4	7	1.3				
Face																						1						1			2			1	.2				
Eye				1								1				1		1	3				1					5	1	2	.9	.2	.4	8	1.4				
Throat											1										1								1	1		.2	.2	2	.4				
Images																																							
General																	1			1									2			.4		2	.4	37	6.6		
Aud.-verbal		2	1		6	6		6	6		4			2			1				1						1		18	17		3	3	35	6.3				
Clrns. vals. by phases	4	2	1	25	18	11	27	24	19	24	22	11	4	21	9	19	28	12	43	34	19	29	39	38	23	27	21	198	215	141									
All phases	7			54			70			57			34			59			96			106			71			554											
Percentages	1			10			13			10			6			11			17			19			13			36	39	25									
Values in 3 degrees	61						220												273																				
Percentages	11						40												49																				

TABLE VIII (O = De)

Clearness values....	1			2			3			4			5			6			7			8			9			All Values			%			Proc. in 3 phases	%	Type of Proc.	%	Class of Proc.	%
Phases.....	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3						
Processes																																							
Visual?	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--					101	64
Sensations	--	--	--	--	--	--	10	--	--	11	1	--	20	--	--	11	--	--	5	--	--	2	--	--	1	--	--	60	1	--	38	.6		61	39	61	39		
Images	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--			38	24		
Spot	--	--	--	--	--	--	--	--	1	--	2	--	--	2	2	--	3	1	--	3	2	4	9	4	1	4	2	5	23	12	4	15	7	38	24				
Kinaesthesis	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--					57	36
Sensations	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--			5	4		
General	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	3	1	--	--	--	--	3	1	--	2	.6	--	4	3				
Arms	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	1	--	--	.6	--	1	.6				
Images	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--			52	33		
Verbal	--	--	--	1	1	1	4	2	1	7	4	--	6	1	1	7	--	1	5	1	--	3	4	1	--	--	--	33	13	5	21	8	4	51	32				
General	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	1	--	--	.6	--	1	.6				
Clrns. vals by phases	--	--	--	1	1	1	14	2	2	18	7		26	3	3	18	3	2	10	5	2	12	15	5	2	4	2	101	40	17										
All phases				3			18			25			32			23			17			32			8			158											
Percentages				2			11			16			20			15			11			20			5			64	25	11									
Values in 3 degrees				3									98									57																	
Percentages				2									62									36																	

TABLE IX (O = Rs)

Clearness values....	1			2			3			4			5			6			7			8			9			All Values			%			Proc. in 3 phases	%	Type of Proc.	%	Class of Proc.	%
Phases.....	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3						
Processes																																							
Visual.....																																					134	59
Sensations.....	16	1	..	20	8	1	6	6	1	6	6	..	5	7	3	3	3	2	3	2	..	1	1	1	..	..	..	60	34	8	26	15	4	102	45	102	45	....	....
Images.....	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	32	14	....	....	....	....
Spot.....	..	..	..	..	2	..	..	2	..	..	..	..	..	1	..	..	1	..	..	1	..	..	..	..	..	..	..	..	6	1	..	3	4	7	3	....	....	....	....
Associations...	..	1	..	2	6	..	4	2	3	..	1	..	..	1	..	..	2	1	..	1	1	..	..	..	..	..	..	6	14	5	3	6	2	25	11	....	....	....	....
Auditory Images...	..	..	..	..	1	..	..	1	..	1	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	1	3	..	.4	1	..	4	2	4	2	4	2
Cutaneous images..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	....	....	19	8
Pressure.....	2	1	..	4	4	..	..	..	..	1	3	2	..	..	..	..	2	..	..	..	..	..	..	..	..	..	..	9	9	1	4	4	.4	19	.8	19	8	....	....
Organic sensations..	..	1	..	..	1	..	..	1	..	..	2	..	1	1	..	..	..	..	..	..	..	..	..	..	..	..	..	1	6	..	.4	3	..	7	3	7	3	....	....
Kinaesthesis.....	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	....	....	64	28
Sensations.....	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	24	10	....	....	....	....
Muscular:																																						
General..	..	..	..	2	2	..	..	1	..	..	..	..	..	..	..	..	1	..	2	..	..	1	..	..	..	..	..	5	4	..	.2	2	..	9	4	....	....	....	....
Shoulders...	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	1	1	..	.4	.4	..	2	.8	....	....	....	....
Arm.....	1	..	..	..	..	..	2	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	3	1	..	1	.4	..	4	2	....	....	....	....
Head.....	1	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	1	..	1	..	..	..	..	..	..	..	..	2	2	..	.8	.8	..	4	2	....	....	....	....
Eye.....	..	..	..	..	..	..	..	1	..	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2	1	..	.8	.4	..	3	1	....	....	....	....
Forehead....	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	1	1	..	.4	.4	..	2	.8	....	....	....	....
Images.....																																						
General.....	3	2	..	5	3	1	3	2	1	2	2	..	2	..	..	1	3	..	1	1	..	..	..	..	..	..	1	18	13	2	8	6	.8	33	14	40	18	....	....
Hand.....	..	..	..	1	2	..	..	..	..	1	1	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	2	4	..	.8	2	..	6	3	....	....	....	....
Aud.-verbal....	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	.4	..	..	1	4	....	....	....	....
Clrns. vals. by phases	24	6	—	35	30	2	15	16	6	15	14	—	8	11	4	5	15	3	7	5	1	2	1	1	1	..	..	112	99	17									
All phases.....	30			67			38			29			23			23			13			4			1			228											
Percentages.....	13			29			16.6			13			10			10			6			2			4			49	43	8									
Values in 3 degrees	97						113												18																				
Percentages.....	42						50												8																				

TABLE X (O = Ru)

Clearness values....	1			2			3			4			5			6			7			8			9			All Values			%			Proc. in 3 phases	%	Type of Proc.	%	Class of Proc.	%
Phases.....	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3						
Processes																																							
Visual.....																																					261	36
Sensations.....	77	20	3	9	8	1	2	5	1																			88	33	5	12	4	.7	126	17	126	17		
Images.....																																				135	19		
Spot.....		1		3	7	1	3	3	2												1							6	11	4	.8	2	.5	21	3				
Associations....		10	13	23	39	7	6	7	5								1	3										29	57	28	4	8	4	114	16				
Organic sensations..							2	5	3				30	29	12	8	9	4	13	3	2	5	6	1				58	52	22	8	7	3	132	18	132	18	132	18
Kinaesthesis.....																																					338	46
Sensations.....																																				288	39		
Muscular:																																							
General.....								2					1			2	4		4	3		3	2	1				10	11	1	1	2	.1	22	3				
Shoulder.....														2															2			3		2	3				
Eye.....			1	7	2	2	4	7					2	2	1		2			1	1							14	14	4	2	2	.5	32	4				
Verbal.....				6	9	8	33	37	14					3	2						2		1					39	50	26	5	7	4	115	16				
Strain:																																							
General.....									1				1	1	1				1			1	1	1				3	2	3	.4	.3	.4	8	1				
Head.....				6	7	1	18	6	1	1	2		6	8	3	6	4	3	1	3	3	2	2	1				40	32	12	5	4	2	84	11				
Forehead.....					1			1					2	2	1	2	3	1										4	7	2	.5	1	.3	13	2				
Eye.....					1		3	2	2				1	1				1		1								4	5	3	.5	.7	.4	12	2				
Images.....																																				50	7		
Verbal.....	1				2	1	18	17	6				1	2		1							1					21	22	7	3	3	1	50	7				
Clrns. vals. by phases	78	31	17	54	76	21	89	92	35	1	2		44	50	20	19	23	12	20	11	8	11	13	4				316	298	117									
All phases.....	126			151			216			3			114			54			39			28						731											
Percentages.....	17			21			30			4			16			7			5			4						43	41	16									
Values in 3 degrees .	277						387												67																			
Percentages.....	38						53												9																			

Results. Tables VII-X present a tabulation by observers with respect to kind of process, degree of clearness, and phase of perception. They include only processes relevant to the perception and not those of the total mind.

When the various kinds of process are considered with regard to their frequency in the nine classes, wide individual variations in relative clearness appear; but they largely disappear again when the nine degrees are reduced to three.

For example, we find upon inspection of the Tables that the visual sensory complexes occurred fairly well distributed under the nine values for C and Ra, while they all belonged to Ru's area of maximal clarity, and with few exceptions in the range of moderately clear components for De. And again, with reference to the kinaesthetic complexes, which are common factors for all observers, there is a decided tendency for them to be of very low level in the case of C, but of moderate clearness for all others. The extent of distribution does seem to bear some relation to the predominant type of process, *e. g.*, C, De, and Ra, who reported visual sensations under at least seven of the nine categories, possess a predominance of visual sensations over visual imaginal complexes, while Ru, who reported no visual sensations of less than degree 3, shows a slightly higher percentage of visual imagery than of sensational material. But no fixed relation as regards relative clearness of sensation and image of the kinaesthetic kind can be made out, possibly because these processes are all alike—as some writers contend—sensational in character. Again, no constant relation obtains between the clearness of sensations directly evoked and the frequency and clearness of those indirectly initiated. For example, C, whose visual processes range from 1 to 9 degrees in clearness, reveals a higher percentage of kinaesthesis, while Ru, who reported visual processes only as of the highest degrees, also possesses a much higher percentage (39) of kinaesthetic than of visual sensations (17). Neither is there apparent a direct relationship between the vividness of visual and of kinaesthetic sensations. In C's case, where the visual processes were widely distributed, kinaesthesis showed a tendency to run very low in clearness, whereas in the case of Ru, where the visual processes were concentrated at a high level, the kinaesthetic sensations were distributed, for the greater part, over the middle values. The directly and indirectly initiated sensations then seem to vary independently of each other both as to frequency and to clearness.

If now we consider all degrees of clearness under three large groups, maximally clear, moderately clear, and obscure, a grouping which our preliminary experiments seem to justify, then these wide irregularities in large measure disappear. The difference is revealed in Table XI which brings together the footings of the individual results (in Tables VII-X). The highest frequency (49%) falls within the field of moderate clearness, while the other regions are, in the totals, virtually the same (26% and 25%). All observers agree in the large number of processes of moderate clearness; though they differ

in distribution between the two extremes of clarity and obscurity.

TABLE XI

Obs.		Clearness Values									Totals For All Values		
											Phases		
		1	2	3	4	5	6	7	8	9	1	2	3
C	Totals.....	7	54	70	57	34	59	96	106	71	198	215	141
De		0	3	18	25	32	23	17	32	8	101	40	17
Ra		30	67	38	29	23	23	13	4	1	112	99	17
Ru		126	151	216	3	114	54	39	28	0	316	298	117
C	Percentages....	1	10	13	10	6	11	17	19	13	36	39	25
De		0	2	11	16	20	15	11	20	5	64	25	11
Ra		13	29	16.6	13	10	10	6	2	4	49	43	8
Ru		17	21	30	4	16	7	5	4	0	43	41	16
	Grand totals...	163	275	342	114	203	159	165	170	80	727	652	292
	Percentages....	10	16	20	7	12	10	10	10	5	44	39	17
	Totals in 3 levels	438			818			415					
	Percentages....	26			49			25					

So much for the organization of the perceptions in cross-section; let us also regard the temporal course. We recall from Experiment 1 that processes indirectly evoked compose, almost exclusively, every phase but the first. Furthermore, the results of Experiment 3 show that these indirectly initiated processes are generally less clear than the visual sensations, which, in a large measure, occupy the focus of attention. Thus the perception temporally undergoes a reorganization not only with respect to kind of process but also in regard to the degree of clarity of the various components. In the first phase are usually to be found only visual sensations, but of maximal clearness, while in the second there are, as a rule, accessory processes, but standing at a lower level of clearness. This fact seems to indicate a decrease in clearness from phase to phase of the perceptual complex. In Table XII we have exhibited the relation of clearness between the processes of the first and second, and of the second and third phases of perception.

In order to maintain a constant standard, the changes were determined by the relation of the highest clearness values assigned in the two phases under comparison, *e. g.*, if both the first and second phases possessed processes of the first

TABLE XII

Observers	1st to 2nd Phase			2nd to 3rd Phase		
	—	+	*O*	—	+	*O*
C	50	25	13	29	19	6
De	27	7	4	8	6	1
Ra	29	13	9	8	2	1
Ru	53	6	30	26	16	17
Totals	159	51	56	71	43	25

degree, then they were considered as having undergone no change, but if the first phase contained a process of degree 1, and the highest of the second phase was of degree 2, it was considered as a decrease in clearness. C, for instance, out of 88 perceptions reported 50 decreases in clearness between the first and second phases, 25 increases, and 13 wherein there were no changes. The symbols —, +, and *O* signify a decrease, increase, or no change, respectively.

Table XII shows, then, that there is always a greater frequency of decreases in clearness than of increases or persistencies. This observation indicates that perception undergoes a change in clearness from phase to phase and usually a decline.

But the perceptual complex suffers not only with respect to clearness from phase to phase, but also in number of components. Inspection of the last three columns of Table XI will make it evident that, with the exception of C, every phase is less rich in processes than the one preceding. Thus perception declines both in clearness and in complexity of component members.

From this investigation we may draw the following conclusions:

1. The various areas of clearness within the perceptual complex, viewed in cross-section, differ as to the frequency of processes. The region of moderate clarity (degrees 3-6) comprises the greatest number of components, while to the perception the areas of focal distinctness and obscurity contribute unequal shares of the remainder. There were many more processes, however in the obscure background which were wholly irrelevant to the perception and which have therefore not been included.

2. In perception, each large region of clearness also shows a predominance of some particular kind of process. The directly evoked processes lie, for the greater part, within the area of maximal clearness, while those indirectly evoked are usually moderately clear, and less frequently obscure.

3. There is usually a gradual decrease in the clearness and frequency of the various processes from phase to phase.

Nevertheless, just as we found in Experiment 2 that, although processes varied as to function, we could not decide on the basis of clearness and frequency alone which component was of the most importance to the perception, so in this experiment we cannot say whether processes with lower frequency but of greater clearness (directly evoked processes) are *ipso facto* of more importance to the perception than processes with a greater frequency and lower degree of clearness (indirectly evoked processes).

D. A Study of the Principal and Accessory Processes in Perception.

Problem and method. As a result of our experiments with objects possessing minimal or only slight significance, we have found that perceptions are composed of typical processes which display particular functions and which vary as to frequency and clearness. The processes are divided into those controlled by stimulus or directly evoked,—in our case the light sensations,—and those indirectly initiated, the kinaesthetic, organic, and imaginal processes. In this part of the investigation we have attempted to determine the relative value of the controlled and uncontrolled processes to the perception of highly significant objects. For this purpose a series of fifty miniature objects[70] was prepared and attached to cards, in order that they might be exposed in the tachistoscope. The objects were purposely chosen to call forth special imagery and kinaesthetic processes. We wished to find out whether the sensations immediately initiated, the imaginal processes, or the processes connected with organic movement bear the chief importance in the perception. According to our purpose, some of the objects were chosen for the possible initiation of auditory imagery (*e. g.*, the bell and whistle), others, for kinaesthesis (*e. g.*, the Indian clubs and hammer), others again (*e. g.*, the rose and sweet peas) to call forth olfactory images.

[70]The series given in the order of presentation included cloves, piece of rubber sponge, match and match-box lid, pickle, bell, burned cigarette, velvet, ginger-snap, scales, whistle, date, Indian clubs, chain, wet chamois, cherry and leaf (artificial), tennis racket, bottle of green liquid, hammer, loaf sugar, lantern with red glass, thumb-tack, rubber ball, coffee grains, slice of lemon, cannon, violets, sand-paper, ball-bat, striped candy, telephone, sweet peas, fur, suit-case, orange peel, firecracker, red rose, ice, dumb-bell, half of English walnut, peanut, slice of onion, red hot wire (heated by electric current), key, chocolate candy, stamp, celery, thorny twig, screw, slice of apple, and pitcher.

These objects were exposed for one second, and introspection was demanded for just the exposure period. The observers were Da, Ra, and Ru. The instructions were:

"Two seconds after a 'ready' signal, an object will be briefly exposed. Observe the object carefully. Give a full introspective account of the (1) meanings, (2) processes, sensational and imaginal, reporting upon their clearness as 'very clear,' 'moderately clear,' or 'very obscure,' and (3) temporal course of the perception."

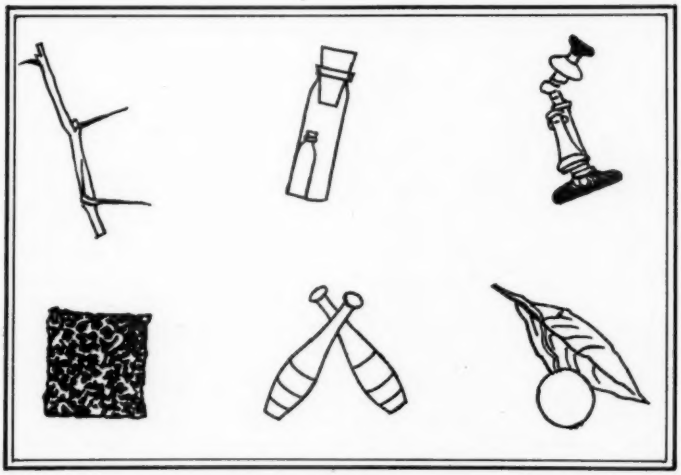


FIG. 2

Results. Table XIII gives a summary of the results of this experiment with respect to the frequency of the directly and indirectly initiated processes. 'P' and 'C' represent respectively peripheral and central processes, and '+' and '—' indicate whether or not a process or a complex was taken by the observer to add to the meaning of the perception.

The figures in the table make it evident (1) that the actual number of all kinds of accessory processes is about the same for perceptions of little or of much meaning (totals 73% and 76%); but (2) that the number of accessory processes *which are relevant and contributory to the perception* are much greater with elaborate (59%) than with slight (32%) meaning. (3) Where the meaning is considerable both the peripheral (36%) and the central (23%) accessories make

TABLE XIII

Obs.		Meaning Slight					Meaning Considerable				
		Direct	Indirect				Direct	Indirect			
			P		C			P		C	
		+	+	—	+	—	+	+	—	+	—
Da	Totals.....	8	9	12	3	3	42	75	32	43	17
Ra		12	1	2	9	3	45	19	3	46	7
Ru		5	6	15	2	2	45	107	25	39	8
Da	Percentages.	23	25	36	8	8	20	36	15	21	8
Ra		44	4	8	33	11	38	16	2	38	6
Ru		16	20	50	7	7	20	48	11	17	4
	Grand totals	25	16	29	14	8	132	201	60	128	32
	Percentages.	27	17	32	15	9	24	36	11	23	6

large contributions to the meaning of the perception. (4) The greatest modification of function appears with the accessory peripheral (organic and kinaesthetic processes) which principally go into intent and effort where perceptual meaning is slight but are incorporated within the perception itself where objects are more richly clothed with properties and relations. (5) A notable individual difference in the perceptual use of indirectly evoked processes appears in the fact that in the cases of Da and Ru the relevant peripheral accessories greatly exceed the direct (visual) complexes where the meaning is rich (for Da 36% and 20%; for Ru 48% and 20%), whereas in the case of Ra the central processes make the greatest contribution (38%).

The relative importance to the perception of the various processes may be considered from still another point of view,—that of attentional clearness. An inspection of Table XIV shows[71] that the visual sensations present the highest frequency in the focus, while the imaginal, organic and kinaesthetic processes are variously distributed throughout all three levels.

Certain differences among the observers must be considered.

Da and Ru are again alike in keeping their central or imaginal processes at a moderate or low degree of clarity, whatever the extent of meaning, (only 3% and 7% for 'very clear') and unlike Ra whose 'very clear' central processes stand at 33% and 27%. We also saw a moment ago that Ra's central processes are relatively numerous and

[71]The symbols c, m, and o represent the various levels of clearness: very clear, moderately clear, and very obscure.

TABLE XIV

Obs.		Meaning Slight									Meaning Considerable								
		Direct			Indirect						Direct			Indirect					
					P			C						P			C		
		C	M	O	C	M	O	C	M	O	C	M	O	C	M	O	C	M	O
Da	Totals.....	7	1	0	9	6	6	1	3	2	30	12	0	38	43	26	10	19	31
Ra		8	2	2	2	0	1	9	0	3	34	7	4	6	7	9	33	14	6
Ru		5	0	0	1	14	6	0	3	1	43	2	0	12	63	57	6	29	12
Da	Percentages.	20	3	0	36	17	17	3	8	6	14	6	0	18	21	12	5	9	15
Ra		30	7	7	7	0	4	33	0	11	28	6	3	5	6	8	27	12	5
Ru		17	0	0	3	47	20	0	10	3	19	1	0	6	28	25	2	13	6
	Grand totals.	20	3	2	12	20	13	10	6	6	107	21	4	56	113	92	49	62	49
	Percentages.	22	3	2	13	22	14	11	6	6	19	4	1	10	20	17	9	11	9

that they make a greater contribution to the perception than do similar processes of the other observers (Table XIII). On the other hand, Ra's organic and kinaesthetic sensations (peripheral accessories) which are fairly meagre show no decided tendency to seek a given level, whereas Ru's are chiefly 'moderate' or 'very obscure' (140 out of 153) and Da's chiefly 'moderate' or 'very clear' (96 out of 128). There seems to be no fixed relation between the clearness of these organic and kinaesthetic sensations and the contribution which they make to the perception, though this matter requires further experimental inquiry.

The results of this investigation indicate then (1) that although the sensations directly initiated compose but approximately 25% of all processes, nevertheless they are of fundamental importance to perception, since they are generally the clearest members and always bear some positive relation to the development of the meaning; (2) that the relative values of the indirectly evoked processes depend primarily upon the observer, both in respect to number, to enhancement of meaning, and to the clearness of the various processes.

There is still another very important question related to the analysis of perception which arises and may be answered from these results; namely, the absolute necessity of organic movement for perception. Each O reported the analysis of fifty perceptual complexes during this investigation. Out of that number, Da reported 10% and Ra 30% which involved no kinaesthesis or organic complexes of any type, sensational or imaginal. Ru discovered some symptom of bodily movement, general or localized, during every trial, although more than a fourth of the peripheral accessories were irrelevant to the perception. The fact that the observers reported complexes in

which such factors were either not present or were not involved indicates that the processes are not a necessity to the perception of objects. This conclusion is further substantiated by the results of Experiment 1, (Table II, Group IV) where over 8% of the perceptual formations brought under the 13 tvpes lacked kinaesthetic or organic factors.[72] We may believe that in these and similar cases the perceptual meaning is simply and directly borne by the visual sensations and possibly the central accessories.

Chapter III

SUMMARY AND CONCLUSIONS

From the combined results of all our experiments, we may conclude that 'visual' perceptions tend, under our conditions, to present typical formations, which are composed of similar processes or members and are similarly organized or. constituted. During the four experiments we have analyzed approximately 1500 perceptual complexes, all of which have revealed forms of integration the same as, or similar to, the standardized forms symbolized in Table II. We find the same component processes reported from perception to perception, whether the perception carries fragmentary, limited, or elaborate meaning. Again, we have found a progressive change in function of the various accessory processes coincident with the modification and the expansion of meaning. This modification will be made evident by a review of Experiments 1, 2, and 4 (3 used the devices of 1), where there is a gradual evolution in complexity of the materials used. The functional modifications seem to follow a definite, temporal sequence; (1) in perceptions with very little meaning, the accessory processes carry intent and they also serve to interpret the primary meaning as a 'nonsense' figure or blot, (2) in perceptions with more meaning, these processes not only interpret, but also aid in specifying and localizing the object and occasionally they are involved in appreciation, and (3) in perceptions with elaborate meanings, the specifying, localizing, and, especially, the appreciative functions become more and more frequent and elaborate. Finally, a general conclusion may be reached as regards the relative value to the meaning of the perception of the 'direct' and the 'indi-

[72] The results of a minor problem (conducted by Miss Davis, one of our observers) where the emphasis is laid upon this particular phase of perception seem further to support our facts. Three observers have thus far reported 44%, 21%, and 4% of their perceptions to be wanting in these peripheral accessory processes.

rect' processes. In all the experiments we have found a predominance of kinaesthetic and organic factors over visual sensations and imaginal processes. But, in spite of the predominance of kinaesthesis in the total number of perceptions, there have been reported in each investigation perceptions which did not involve any symptom of organic movement. The experiments indicate, then, that, although the results, sensational or imaginal, of organic movement are incorporated into many perceptual complexes, their frequent absence goes to show that objects may be perceived without their interposition.

Our results agree in general with the view maintained by several writers,—James, Bagley, Wallaschek, Lehmann, and Titchener,[73]—that the background, sensational or imaginal, is of fundamental importance to the meaning of perception. The kinaesthetic and organic sensations and the imaginal processes under our conditions have consistently formed a setting for the central visual complex, and have supplied more of the derived significance than the 'directly' initiated processes themselves. But we should not go so far as to contend that this 'context' is the meaning,[74] since the process itself is always to be considered as distinct from its function. When meaning is described no single process or group of processes, focal or marginal, can be looked upon as the meaning of the whole complex, but we must consider all of the integrated members as a unit. When we consider that meaning presents stages of elaboration, the lowest being the bare apprehension of a 'meaningless' object, the directly evoked process become of more importance to the significance in the lower stages than the 'fringe' or 'context.' This latter then functionates as a forced searching or seeking for derived, elaborate meaning; which usually fails. Nevertheless, as meaning becomes more elaborate, the accessory processes acquire increasing importance.

Since we have contended for an intimate relation between meaning and process, we cannot agree with the exponents of 'imageless' thought that the two are separate processes. Moore,[75] who has attempted to prove by experiment the presupposition, seems to have fallen into a twofold error; first, he has failed to take into account the stages of elaboration of meaning and, secondly, he has assumed that, if imagery and meaning were synonymous, then imagery must refer to the stimulus itself. Only very elaborate, derived meanings are considered in his results, and as the introspections of our observers show that perceptions under such conditions are very complex, we suspect that Moore left out of account the greater share of contributory processes. As regards imagery, our own results make it appear that the memory-image of the object, whether visual or kinaesthetic, was

[73]James, W., *op. cit.*, I, 258; Bagley, W. C., The apperception of the spoken sentence; a study in the psychology of language, *Am. J. of Psychol.*, 1900, xii, 80; Wallaschek, R., *Psychologie und Pathologie der Vorstellung*, Leipzig, 1905, 188; Lehmann, A., *Grundzüge der Psychophysiologie*, Leipzig, 1912, 603; and Titchener, E. B., *A textbook of psychology*, N. Y., 1915, 367ff.

[74]Titchener, E. B., *ibid.*, 367.

[75]Moore, T. V., The temporal relations of meaning and imagery, *Psychol. Rev.*, 1915, xxii, 177.

much less frequent than images with derived meanings all of which bore a direct relation to the total signification. A comparison, then, of the reaction-times of meaning and of imagery, directly referring to stimulus, would not be a fair determination of the relation of the meaning to imagery, since a good number of the relevant imaginal processes have been disregarded. A qualified statement of this problem by Tolman,[76] while it specifies too far, accords better with our own results.

Our experimental researches seem, then, to justify the following generalizations:

1. 'Visual' perceptions present a number of typical formations, each of which presents its own peculiar mode of integration and is marked by a distinctive temporal course. These formations are variously based upon three kinds of mental processes, (1) visual sensations directly evoked by stimulus, (2) kinaesthetic and organic sensations indirectly evoked (peripheral accessories), and (3) imaginal materials drawn from various sources (central accessories).

2. All 'visual' perceptions of our class have the same general constitution. The visual sensations, directly evoked by stimulus, are usually the clearest processes within the perceptual pattern, while the accessory processes lie chiefly in the region of moderate and limited clearness. The obscurest processes were, for the greater part, not relevant to the perception. During the temporal course of the perception, typical modifications occur, *i. e.*, (1) there is a gradual decrease in the number and clearness of the processes from phase to phase, and (2) there is a readjustment of the various factors themselves, the visual sensations tending toward obscurity while the accessory processes become relatively more prominent.

3. Spatial perceptions of the kind exemplified in our experiments fall into four classes as regards the kind of functions which they perform; namely; figurational ('nonsense' figures), depictive (presentations of specific objects), abstract (reference to a kind or class of objects), and symbolic (a secondary meaning which transcends the 'presented' object). The first correspond to objects which are frequently called 'meaningless,' the second to the customary apprehensions of sense (perception taken in the usual way), while the third and fourth suggest functions which are either intermediate between or else common to perception and thought.[77]

4. The component processes fulfil different functions

[76] Tolman, F. C., More concerning the temporal relations of meaning and imagery, *Psychol. Rev.*, 1917, xxiv, 138.

[77] A special study of these 'higher' forms of perception is well advanced in the Laboratory.

according to the degree of cognitive elaboration. Where the meaning is minimal or slight (as in the bare apprehension of an irregular 'nonsense' figure), the processes first bear the meaning and secondarily reenforce (in the form of effort or intent) a self-instruction to seek further significance in the figure. Where the meaning is moderate or complex, the accessory processes may give in addition a value to the object perceived (appreciative function) or they may establish it in its spatial and temporal relations (localizing function).

5. Meaning is only loosely correlated with the number and degrees of clearness of the indirectly initiated processes (peripheral and central accessories).

6. Kinaesthetic processes are not invariable components of spatial perceptions.

EXTATIC INTOXICATION IN RELIGION*

By JAMES H. LEUBA, Bryn Mawr College, Penna.

In the religions of nearly all savage and semi-civilized peoples, extatic intoxication is regarded as communion or union with the divine; and even in the higher religions, similar conditions enjoy the same consideration. Why should intoxication and extasy be assigned the supreme place in religion?

Religious intoxication is not always produced by drugs. It may arise from physical excitement, from dancing, for instance; or it may be generated by psychic means; those used by the Christian mystics. Although in this brief paper I shall be able to do little more than indicate the connection that exists between drug intoxication and the higher mysticism, I hope to show that despite the diversity of their origin they are closely related to one another by certain psychological characteristics, by the purpose they serve, and by the significance usually ascribed to them. I shall take up successively the several classes of means used to produce intoxication in religious ceremonies, the usual explanation of the exalted character ascribed to these states, and the deeper, more fundamental reason for this fact.

I had probably better say at the outset that I have no intention of reducing mysticism to drunkenness. For the best of the Christian mystics I have a real admiration; they are noble men who, on the whole, have deserved well of humanity. It seems to me childish, however, to pretend to dispose of the subject, as religious writers are wont to do, with vague high-sounding words such as ineffable, infinite, unutterable, absolute, divine. That is not the way to make intelligible the nature and the function of mysticism; it merely encourages a romantic megalomania already too conspicuous among religious believers.

Chemical means, i. e., drugs, are employed almost exclusively by uncivilized peoples in order to produce intoxication during religious ceremonies. Brinton tells us that "in every savage tribe we find a knowledge of narcotic plants which were employed to induce strange and vivid hallucinations or dreams . . . . .The negroes of the Niger had their 'fetish

* The substance of a paper read before the American Psychological Association, December, 1913.

water', the Creek Indians of Florida their 'black drink' for this purpose. In many parts of the United States the natives smoked stramonium, the Mexican tribes swallowed the *peyotl* and the snake-plant, the tribes of California and the Samoyeds of Siberia had found a poisonous toadstool; all to bring about communication with the Divine and to induce extatic visions."[1] The Indians of New Mexico who are "unacquainted with intoxicating liquors . . . find drunkenness, in the fumes of a certain herb smoked through a stone tube and used chiefly during their religious festivals." Among the old Mexicans, a seed called *Oliliuhgue* entered into a vision-producing "divine medicine," which could be obtained only from the priests.[2]

"In the Indic and Iranian cult there was," we are told, "a direct worship of deified liquor analogous to Dionysiac rites." It has even been maintained that the whole Rig Veda is but a collection of hymns for soma worship. The drinking ceremony was accompanied by magical incantations and by religious invocations. During the frequent libations that marked the sacrifice of soma, the officiating priest asked repeatedly for inspiration. He offered the liquor with these words: "O, Indra, accept our offering . . . drink of the soma, thou the friend of prayer and of the liquor; well disposed God, drink in order to intoxicate thyself." "I pour it out into the double cavity of thy belly; may it spread through thy members; may it be sweet to thy taste; may it steal upon thee, O deliverer, veiled as women seeking a *rendez-vous*. Hero with the strong neck, full bellied, strong of arms, O Indra, praised by many, accept the pressed out soma, father of divine energy."[3]

Modern India has not renounced the use of drugs in religious ceremonies. The India Hemp Commission appointed by the English Government to investigate the use of hemp drugs in its Hindoo possessions, reported that several hemp preparations are "extensively used in the exercise of religious practices." They found evidence of the "almost universal use of hemp drugs by fakirs, jogis, sanyasis, and ascetics of all classes, and more particularly by those devoted to the worship of Siva."[4] The hemp plant is believed by priests and people to be a special attribute of that god.

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[1] David Brinton, *The Religions of Primitive Peoples*, pp. 67.
[2] H. H. Bancroft, *Native Races*, vol. I, pp. 566-567.
[3] Galand and Henry, *L'Agnistonia*, vol. I, pp. 162, 155, 249; vol. II, p. 311.
[4] *Report of the India Hemp Commission*, 1893-94, Vol. I, pp. 160, 161, 165

Wine drunkenness was conspicuous in the worship of Dionysos. To the effect of the wine was added that of dancing, music, shouting, and expectation of divine extasy.[5]

But drugs are not the only means of securing the blessed intoxication in which people of every degree of culture find delight. Rhythmic bodily movements, sufficiently violent and long continued, yield results similar in several respects to those of alcohol, stramonium, cohoba, and other drugs. There are in Grosse's *The Beginnings of Art*, interesting descriptions of Australian dances ending in a condition of extatic trance.[6]

As soon as a somewhat spiritual conception of divinity arose, drugs and mechanical means could no longer be regarded as proper means of approaching it. These grossly material methods appeared incongruous with the god-ideas that were taking shape. Furthermore, the disagreeable after-effects of these practices were not easily reconcilable with the theory of god-possession. Yet intoxication was too delightful and gratified too many deep needs to be given up. Thus arose the problem of finding a method of intoxication consistent with the higher conception of the divine nature. This problem was solved by the discovery of psychic methods, which, associated with drugs, appear already in Dionysiac and in Soma worship. In the Yoga practices, physical and psychical means are equally employed. In Christian mysticism, only the latter are acknowledged, although physical influences have not ceased to lend their aid. Even at the present day, physical means are not altogether excluded; in so-called "revival meetings," for instance, the monotonous repetition of rhythmical songs, accentuated by shouts and bodily movements, help to produce a condition similar to that in which the dervish attains partial anaesthesia and visions of Allah.

Why this extraordinary association of extatic intoxication with the gods? The common and well-known explanation is that intoxication in bringing visions and, with them, alleged superhuman powers of healing, of making rain, of destroying enemies, of forecasting the future, of controlling spirits, etc., raises man to the level of the gods.

Revelations and specific powers account perhaps sufficiently for the connection established in the unenlightened mind between intoxication and a higher world; but these characteristics do not fully explain its irrestible attraction. There are other

[5] See the description in Erwin Rohde's *Psyche, Seelencult und Unsterblichkeitsglaube*, 4th ed., Tubingen, 1907, vol. II, pp. 9-10.

[6] See chap. III.

and more fundamental reasons than those for the supreme place granted in religion to intoxication and extasy. The allurement of intoxication arises not so much from the belief that it affords esoteric knowledge and a share in the power of the Invisibles, as from the gratification it provides for certain deep needs and cravings. The truth of this statement is borne out by the fact that when intoxication ceases to be regarded as union with God and as a source of superhuman power, it continues to inspire the pen of the poet and to entice the unwary often beyond his power of resistance.

Some of these more fundamental values are indicated in the quotations I have given from religious customs of various peoples. They will appear more clearly and completely in instances of intoxication disconnected from any relation with religion. I quote one of the classical descriptions of the wonders worked by alcohol, "I send you," writes Colonel Ingersoll, "some of the most wonderful whiskey that ever drove the skeleton from the feast or painted landscapes in the brain of man. It is the mingled souls of wheat and corn. In it you will find the sunshine and the shadow that chased each other over the billowy fields; the breath of June, the carol of the lark, the dew of night, the wealth of summer and autumn's rich content, all golden with imprisoned light. Drink it, and you will hear the voices of men and maidens singing the 'Harvest Home' mingled with the laughter of children. Drink it, and you will feel within your blood the star-led dawns, the dreamy, tawney dusks of many perfect days. For forty years this liquid joy has been within the happy staves of oak longing to touch the lips of men." If all this and nothing worse was alcohol's gift to man, it would be in truth a "divine" beverage.

The information that has resulted from careful observation of the effect of narcotic drugs is still far from complete. We know, however, that their action may vary from person to person, and even in the same person under different circumstances, I shall mention only the more usual and constant effects to which these drugs owe their place in religion as well as outside of it. The drug devotees disregard all except those particular effects which are to them desirable; my purpose authorizes me to do likewise.

The effect of mescal (anhalonium lewinii), the very remarkable drug used in the religious festivals of Mexican and American Indians, has been studied by Dr Weir Mitchell, Havelock Ellis, and others. The most noteworthy of its effects are marvellously beautiful color-hallucinations. Of these

the first investigator named wrote, "The display which for an enchanted two hours followed, was such as I find it hopeless to describe in language which shall convey to others the beauty and splendor of what I saw."[7]

Although there is a certain insensitiveness to fatigue, motor weakness and disinclination to activity is experienced. Ellis who notes this fact, remarks that this only throws "the subject of mescal intoxication more absolutely at the mercy of the waves of unfamiliar sensory impetus which strike him from every side. Every sense is affected . . . the simplest food seems to possess an added relish . . . and to the sense of touch, the body seems as unfamiliar as everything else has become." "The 'trailing clouds of glory,' the tendency to invest the very simplest things with an atmosphere of beauty, a 'light that never was on sea or land,' the new vision of even 'the simplest flower that blows,' all the special traits of Wordsworth's poetic vision correspond as exactly as possible to the actual and effortless experience of the subject of mescal."[8]

A uniform physiological effect of the drugs with which we are concerned is a reduction of the efficiency of the higher nervous system. They produce a partial break down of the interrelations by which the higher nervous centres exercise their control over the lower. The hilarious mood into which *cannabis indica*, ether, alcohol, and other drugs plunge their devotees, is due probably in part to this physiological action. In the description of his experiments with *cannabis indica* and ether, Dunbar wrote, "Time seemed to have no existence. I was continually taking out my watch thinking that hours must have passed, whereas only a few minutes had elapsed. This, I believe, was due to a complete loss of memory for recent events." Amnesia accounts, in part at least, for the freedom from all care and worry noted by this experimenter as well as by every other.

The beginning of the action of hasheesh is described thus by Dr. V. Robinson,[9] "The flood of laughter was loose, the deluge of mirth poured forth." One of the persons with whom he was experimenting exclaimed, "Cast aside all irrelevant hypotheses, and get to the laughing. I proclaim the supremacy of the laugh, laughter inextinguishable, laughter eternal, the divine laughter of the gods."

[7] *The effect of Anhalonium Lewinii*, Brit. Med. Jr., vol. II, 1896, pp. 1625-1628.
[8] *Popular Science Monthly*, vol. LXI, 1902, pp. 52-71.
[9] *An Essay on Hasheesh*, Med. Rev. of Reviews, New York, 1912.

The more important psychological consequence of the reduced efficiency of the higher nervous centres is the partial or total removal of the checks imposed upon us by society and logic. This means a turning away from the insistent purposes of life, a relief from daily tasks and besetting unpleasant memories. The "primary" self enjoys a period of rest from the war waged against it by the social self. Thus, there comes recovery from the insufferable staleness to which we are sometimes brought by the unremitting demands of civilized life. Great and many are the evils into which people are enticed simply through the dullness of their existence. Tormented by the yearning for something to stir up the sluggish organism and restore a keen sense of life, man is often induced to seek excitement in drugs and in other forms of stimulation.

The need for relaxation by excitation is so universal that means of gratification have everywhere, and at all times, been sanctioned by society. Sacred and secular festivals, to which various purposes may be assigned, but which serve primarily to refresh through relaxation, form a part of the order of every society. When the faculty of Paris threatened to abolish the Feast of Fools, a petition was presented with the following argument, "Wine casks would burst if we failed sometimes to remove the bung and let in air. Now we are all ill-bound casks and barrels which would let out the wine of wisdom if by constant devotion and the fear of God we allowed it to ferment . . . .Thus on some days we give ourselves up to sport, so that with the greater zeal we may afterwards return to the worship of God." When one means of refreshing the organism becomes impossible another is substituted.

The removal of social checks and of logical constraint manifests itself in a delightful sense of freedom and of power. In intoxication the galling limitations of our ordinary selves seem gone. One of Robinson's subjects exclaimed, throwing off his blanket, "Throw off the bonds of all existence." To feel that impediments vanish before the fiat of one's will, that one is equal to every demand and can soar above all obstructions, is an entrancing experience indeed. What matters it, if, as in ordinary dream, this conviction be unfounded? The delight remains a real part of the experience.

The weakening of critical ability leads, in addition, to the liberation of the fancy. In intoxication one enjoys all the pleasures of untrammeled imagination. Its quality, judged objectively, may not be high, but the subject thinks otherwise and is proudly happy.

Perhaps the most insidious of the allurements of ecstatic intoxication is an intensification of the indescribable sensational and affective background of consciousness. If normally the vital organs are only faintly represented in consciousness, they provide nevertheless an essential part of the background of consciousness. The significance of these obscure feelings is well known to the student of mental disorders; their disappearance or alteration may cause profound mental perturbation and may lead to strange hallucinations. The first stages of intoxication instead of removing, apparently intensify both the sensational and the pleasurable aspects of this somatic background. When the brakes and the fly wheels which control the primary self are removed, it seems as if vital organs reawakened to sentiency, and their multitudinous voices are lifted in a paeon of life. Nothing but sexual erethism compares with the delights of this awakening of certain ordinarily silent parts of the organism.

Philosophic poets may interpret this experience as an upward surge of the Breath of Life, the *Elan Vital,* freed from the opposition of that Other, the alien Reason. It may please them to think that "through the intermediacy of organic life, we correspond, if confusedly, with the universe." Or, they may turn to the speculations of Frederick Meyers, and see in it a transient reinvasion of the focus of consciousness by vital parts of the organism which, in the far distant past, were the chief source of sentiency. Be that as it may, we shall, I trust, agree that the primary and essential value of the intoxication consciousness to the performer of religious rites, lies not in any alleged superhuman knowledge and power, but in other very substantial results. Intoxication and extatic states possess in themselves,—i. e., independently of an interpretative connection with the divine—a delightful, sensuous, rapturous quality; they bring deliverance from the fatigues, the restraints and tensions of the daily struggle, and they create a sense of unlimited possibility and exhaustless energy. In these effects, characteristic alike of the extasy of the Christian mystic and of the drug intoxication of the lowest savage, is to be found the deeper significance of the notion that in extasy man communes with the gods.

MINOR STUDIES FROM THE PSYCHOLOGICAL LABORATORY OF CORNELL UNIVERSITY

Communicated by E. B. TITCHENER and E. G. BORING

XXXVII. THE WEBER-FECHNER LAW AND SANFORD'S WEIGHT EXPERIMENT

By MYRL COWDRICK

In the Cornell Laboratory we have records ranging from 1906 to 1917 of 89 performances of Sanford's weight experiment[1] by 48 observers. Ten of these observers performed the experiment only once; 32 of them did it twice; four, three times; and one, four times. Thus of the 89 experiments[2] 43 were performed after an initial experiment, *i. e.*, after a certain amount of practice. The average weight (in grams) of every one of the five piles of envelopes was computed both for the total 89 experiments and for the 43 experiments performed after some practice. Since the five piles in this experiment mark off four equal sense-distances, we may arbitrarily call the intensities of sensation (S) for the successive piles, 0, 1, 2, 3, and 4. The corresponding averages of the stimulus (R, av. weight of the envelopes in a pile in grams) are then as follows:

S:	0	1	2	3	4
R (av. total 89 exps.):	7.80	16.97	31.71	53.53	84.11
R (av. 43 exps. after practice):	7.75	16.53	30.43	52.17	83.93

The ratios between these two sets of R's are respectively:

2.17, 1.92, 1.69, 1.57;
and 2.14, 1.84, 1.71, 1.61.

Since the ratios are in neither case constant the Weber-Fechner Law is not realized, although it is approximated. The continuous decrease of the ratio from the lighter to the heavier piles shows that the actual curve is one of less eccentricity than is the logarithmic curve of the Weber-Fechner formula.[3] One such less eccentric function is that

[1] E. B. Titchener, *Experimental Psychology*, vol. II, 1905, pt. i, 33f.; pt. ii, 82ff.; E. C. Sanford, *A Course in Experimental Psychology*, 1898, 340f., 413f.

[2] The cases preceding add up to 90, but the data for the first trial by one observer who did the experiment twice are missing.

[3] Of course we must not generalize for a range wider than the actual limits of our experiment. The decreasing ratios might increase with still heavier piles, as do Ebbinghaus' ratios for brightness: 2.3, 2.1, 2.1, 1.8, 1.7, 1.7, 2.0; H. Ebbinghaus, *Grundzüge der Psychologie*, I, 1905, 520.

proposed by Fullerton and Cattell,[4] in which S is proportional to the square root of R.[5] The general equations for these two functions are:[6]

Weber-Fechner	$S = k \log R + a$
Fullerton and Cattell:	$S = c\sqrt{R} + b$

We adjusted both sets of averages (the 89 cases and the 43 cases after practice) by the method of least squares[7] to these two equations, thus determining the most probable values of the constants $k, c, a,$ and b.

Since the ratios between the two lightest piles (2.17 and 2.14) depart furthest from constancy, it appears that the Weber-Fechner Law holds more closely for the four heavier piles. Therefore we repeated our computations, omitting the average for the lightest pile.

The most probable equations resulting from all eight adjustments by the method of least squares are given in Table I.

TABLE I

MOST PROBABLE EQUATIONS BY THE METHOD OF LEAST SQUARES

	Weber-Fechner $S = k \log R + a$	Fullerton and Cattell $S = c\sqrt{R} + b$
Average of total 89 experiments:		
5 intensities ($S = 0$ to 4).....	$S = 3.89 \log R - 3.64$	$S = .623\sqrt{R} - 1.616$
4 intensities ($S = 1$ to 4).....	$S = 4.40 \log R - 4.52$	$S = .592\sqrt{R} - 1.383$

[4] G. S. Fullerton and J. McK. Cattell, *On the Perception of Small Differences*, 1892, esp. 152ff.

[5] The formula of Fullerton and Cattell is simply a special case of the relation proposed by Plateau, Grotenfelt, and others, *viz.*, that equal R-ratios correspond to equal S-ratios. The formula for this hypothesis is $S = c R_p + b$. In the formula of Fullerton and Cattell, $p = 0.5$. See Titchener, *op. cit.*, pt. ii, 69; W. Wundt, *Physiologische Psychologie*, I, 1908, 640.

[6] The constants of proportionality are k and c. The constants a and b are so taken that the values of S come out in the arbitrarily assumed scale: 0, 1, 2, 3, 4. Obviously the value $S = 0$ is a fairly heavy weight, but the constants could readily be altered without readjusting the equations, for any other scale of S that might be desired. The constant a also includes the unknown value "$k \log r$," since the unit of R is taken here as the gram and not as the value of the stimulus limen, r; see Titchener, *op. cit.*, pt. ii, xxviii.

[7] We used a linear method of adjustment by least squares; see L. D. Weld, *Theory of Errors and Least Squares*, 1916, 73f., 89f., and, in general, 65-103.

An adjustment to Plateau's ratio-hypothesis (see note above) would necessarily have given a closer approximation, since there are three constants instead of two to be determined; but to be able to adjust with little error for three constants when there are only four or five observational values would not be positive evidence in favor of the hypothesis. Since the adjustment of an exponential equation is a laborious matter (*cf.* Weld, *op. cit.*, 178-180) and since the results would have little significance, we have not attempted it.

TABLE I—*Continued*

Average of 43 experiments after practice:		
5 intensities ($S = 0$ to 4).....	$S = 3.46 \log R - 3.01$	$S = .677 \sqrt{R} - 1.892$
4 intensities ($S = 1$ to 4).....	$S = 4.45 \log R - 4.56$	$S = .587 \sqrt{R} - 1.311$

We can measure the adequacy of the two hypotheses in all cases if we compute from every equation the theoretical values of R which that equation gives for every value of S, subtract this theoretical R from the R observed for the same S, square this difference, and then find the sum of these squares for all values of S. This sum of the squares of these deviations of observed values from theoretical values constitutes a measure of the degree with which an hypothesis is approximated. In the instances with which we are at present dealing the sums will, however, tend to be higher when the five squares for the five intensities are added than when the four squares for the four intensities are taken. Accordingly we have divided every sum by the number by which the normal equations are overdetermined (three or two)[7a], in order to get comparable values. These measures are given in Table II.

TABLE II

MEASURES OF THE DEGREE WITH WHICH THE TWO HYPOTHESES ARE APPROXIMATED BY THE OBSERVED DATA

Sums of the squares of the deviations of the average observed values from the theoretical values (computed from the least square equations of Table I), divided by the number of overdeterminations.

	Weber-Fechner	Fullerton and Cattell
Average of total 89 experiments:		
5 intensities.....	28.014	5.145
4 intensities.....	6.783	2.578
Average of 43 experiments after practice:		
5 intensities.....	20.180	25.527
4 intensities.....	3.562	5.223

From inspection of Table II we may draw for our data the following conclusions:

(1) In the complete experiment (all 89 cases, 5 intensities) the formula of Fullerton and Cattell represents the actual results much more adequately than does the Weber-Fechner Law (5.145 *vs.* 28.014).

(2) The limitation of the range of the experiment by the omission of the least intensity increases the approximation of the observed data

[7a] *Cf.* W. W. Johnson, *Theory of Errors and Method of Least Squares*, 1915, 108.

to both formulae, but still leaves a decided difference in favor of the formula of Fullerton and Cattell (2.578 *vs.* 6.783).

(3) With practice the observed results approach the form of the Weber-Fechner Law and depart from the function of Fullerton and Cattell, so that the former hypothesis now becomes the more representative (25.527 *vs.* 20.180).[8]

(4) With the more limited range of intensities after practice the approximation to both hypotheses is greatly improved, as it was without practice; and the Weber-Fechner Law remains the more representative hypothesis, as it was after practice for the full range.

(5) If the equations of Table I are plotted together with the curves of the observed values, it will be found that the curve of actual values lies always between the two hypotheses; with practice, nearer the logarithmic curve; without practice, nearer the curve of the square root of the magnitude. Thus it appears that the formula of Fullerton and Cattell deviates from the logarithmic function of the Weber-Fechner Law in the proper direction, but deviates too far. Whether after great practice with Sanford's weights any correction of the Weber-Fechner formula in the direction of the equation of Fullerton and Cattell would be necessary, cannot be said.[9]

XXXVIII. An Example of the Fractionation of Data From the Method of Constant Stimuli for the Two-Point Limen

By L. B. Hoisington

We present herewith the results of a determination of the limen of dual impression upon the skin, by the method of constant stimuli,[1] in which the data have been fractionated and dealt with separately for every fraction. Our problem is analogous to that undertaken by Fernberger for lifted weights (*The Effects of Practice in Its Initial Stages in Lifted Weight Experiments and Its Bearing upon Anthropometric Measurements*).[2] We have, however, fractionated more completely than Fernberger, and have thus been able to extend our treatment to more general conclusions.[3] On the other hand, we have intended our case to be merely an illustration of the manner in which such data may be treated, for we used but two observers; whereas Fernberger had ten subjects.

The experimental work was performed by A. M. Palmer and P. R. Dickinson, both of whom accepted opportunities to enter the National Service at a time when the computation of their results was

[8] Titchener notes that the Weber-Fechner law is approached with practice; *op. cit.*, pt. ii, 83.

[9] We have noted that Plateau's law will approximate the observations, but that with so few determinations this approximation indicates little. Merkel's law (*cf.* Titchener, *op. cit.*, pt. ii, 69; Wundt, *op. cit.* I, 635 ff.), the straight line, is obviously inappropriate.

[1] E. B. Titchener, *Experimental Psychology*, II, 1905, i, 92-104; ii, 248-258; E. G. Boring, this Journal, 28, 1917, 280-293.

[2] S. W. Fernberger, this Journal, 27, 1916, 261-272.

[3] See Boring, this Journal, 27, 1916, 315-319; Fernberger, *Psychol. Bull.*, 14, 1917, 110-113; Boring, this Journal, 28, 1917, 280-293.

hardly more than begun. The writer is, therefore, indebted to these experimenters for data discussed in the present paper.

P and *D* worked together, the one acting as observer when the other experimented. They worked upon the forehead with the Griesbach aesthesiometer, using blunted conical rubber points applied at a pressure of 10g. The observer lay upon a couch; after every fifth series he rose and moved about in order that he should not become sleepy. He made his judgments before the points were removed from the skin. His ability to make the kind of judgment required was assured by preliminary practice-series. The experiment proper was concluded in 15 sessions; 10 or 15 series were taken at every session. A session always began with 5 'warming-up' series, which were discarded. The instructions were as follow: "After the signal 'ready,' you will be given a cutaneous stimulus on the forehead. You are to make an immediate judgment of 'one' or 'two'. The judgment 'two' is to stand for two discrete impressions; all other impressions are to be judged as 'one.' Make every judgment independently, without reference to any preceding impression. Keep as constant an attitude as possible;[4] if for any reason your attitude changes, so that you are in doubt about a particular impression, ask to have it repeated."

Five values of stimulus were used: 10, 11, 12, 13, and 14 mm. The total number of series was 200. These, for purposes of fractionation, were divided into groups of 100, of 50, and of 25. For every one of these fractions (15 in all[5]) we have computed the limen and the measure of precision (h), using Urban's tables[6], the probable error of the limen[7], and the sum of the squares of the deviations of the actual percentages from the theoretical.

1. *Practice.* Table I shows the values of the limen for all fractions, and Table II the corresponding values of h. There is (in the regular sense of the term) no practice-effect. The limens for both *O*'s, on the contrary, increase slightly from the first 100 to the second 100. If we examine the 50's and the 25's we see that this increase is not regular. There may, nevertheless, be some general tendency toward increase which is partially obscured by the great variability that occurs when the number of cases is few. If we plot the curves for these limens, by groups of 25 series, we note a general tendency toward

[4] On the advantage of a constant attitude in psychophysical judgments, see S. S. George, this JOURNAL, 28, 1917, 1-37, esp. 33-36.

[5] *I. e.*, one group of 200 series, two 100's, four 50's, and eight 25's.

[6] In the case of the total group of 200 series there were six instances of half percentages. For these percentages we interpolated in Urban's tables for P and γP by fitting a parabola through three adjacent points. The method is more accurate than a straight-line interpolation. It makes no difference in the case of the half-percentages whether the interpolated point lies between the first two or the last two of the three points. On a similar case of parabolic interpolation see F. M. Urban, *The Application of Statistical Methods to the Problems of Psychophysics*, 1908, 124 f.

We checked the additions by the use of a checking table that gives the sums of the five values of Urban's tables for every value of x and p. This table is now in process of compilation by Dr. G. J. Rich; it is to be hoped that he may soon be able to publish it.

[7] For the manner of computation of the probable error of a limen, account being taken of the weighted number of cases, see Boring, this JOURNAL, 27, 317.

TABLE I

LIMENS (CM.)

Obs. *D.*

	Grouping by Series			
	By 25's	By 50's	By 100's	Total 200
1	12.119	12.348	12.214	12.348
2	12.551			
3	12.234	12.109		
4	11.981			
5	12.822	12.501	12.485	
6	12.229			
7	12.395	12.483		
8	12.548			

Obs. *P.*

	Grouping by Series			
	By 25's	By 50's	By 100's	Total 200
1	11.648	11.538	11.537	11.642
2	11.434			
3	11.452	11.532		
4	11.599			
5	11.658	11.578	11.667	
6	11.498			
7	11.710	11.783		
8	11.826			

TABLE II

MEASUREMENT OF PRECISION (h)

Obs. *D.*

	Grouping by Series			
	By 25's	By 50's	By 100's	Total 200
1	.4052	.3994	.4498	.4638
2	.3987			
3	.5740	.4986		
4	.4391			
5	.3565	.4151	.4828	
6	.4857			
7	.5153	.5696		
8	.6136			

Obs. *F.*

	Grouping by Series			
	By 25's	By 50's	By 100's	Total 200
1	.4128	.3837	.3970	.4540
2	.3719			
3	.3368	.4013		
4	.4765			
5	.3966	.4185	.3620	
6	.4424			
7	.2420	.3223		
8	.3834			

increase which appears by inspection to be almost as marked as in the true practice-curve of *h* for Fernberger's Subject I.[8] If, finally, we compute by the method of least squares the most probable straight line for our two curves, we find a general tendency throughout the span of 200 series for the limen to increase. The increase thus indicated is for *D* 0.292 mm. (2.4%), and for *P* 0.267 mm (2.3%).[9]

The practice-effect upon *h* is not the same for the two *O*'s when all eight of the groups of 25 are considered. Plotting the curves by series, as above, we find for *D* the expected increase in the measure of precision to be 0.161 (35%), while the corresponding value for *P* is —0.059 (13%), a slight decrease. If, however, we plot the curve for the first six of the 25's there is, as in the case of *D*, a noticeable increase; the amount is 0.086 (19%). This discrepancy is accounted for by the fact that the last sessions were held after *P*, together with several others of his college fraternity, had enlisted in the army. It is probable that the constancy of his attitude was thereby greatly disturbed.

2. *Dependence of a Limen upon the Number of Observations on which It is Based.* Table III shows the probable errors of the limens. Since these values vary inversely with the square root of the weighted number of cases, we get a decrease of the average probable error as the number of series is increased from 25 to 200. An eight-fold increase in number of series (25 to 200) reduces the probable error of the limen, in the case of *D*, to one-third (.1104 to .0378) and, in the case of *P*, to less than one-third (.1294 to .0378).

The question how many series we must take in determining a limen depends in part upon what we mean to do with the limen when we get it. If we intend, as is usual, to compare it with another limen, then we must take enough series to reduce its probable error to a value which will give to the difference between it and the limen with which we compare it the probable correctness that we desire. We can not settle mathematically what probable correctness we shall regard as significant; we must decide the question in accordance with our scientific judgment in the particular case. Probably most psychologists would at present regard a probable correctness of 98% as very significant and one of 75% as not very significant.[10]

Suppose, for example, that we should wish to compare a limen taken from *D* with another limen which shows on the average the same degree of precision. If we found a difference of .484 mm. between the limens, then we can show by the proper computations that 25 series would be enough to establish this difference with a probable correctness of 98%. If the difference were only .165 mm., 200 series must needs have been taken to give a probable correctness of 98%. But 25 series would give for a difference of about .165 (exactly .156 mm.) a probable correctness of 75%. It appears, therefore, under our assumed condition, that 200 series would give a probable correctness of about 98% where 25 series would give a probable correctness of about 75%. It also appears that highly significant differences could be obtained from less than the usual 100 series if the difference were at all large.

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[8] Fernberger, *Psychol. Rev. Monog.*, No. 61, 1913, 42.

[9] For a general discussion of the effect of practice upon the limen for dual impression see G. M. Whipple, *Manual of Mental and Physical Tests*, I, 1914, 254 f. and Bibliography; esp. L. Solomons, *Psychol. Rev.*, 4, 1897, 246-256; G. Tawney, *Philos. Stud.*, 13, 1897, 163-222.

[10] This JOURNAL, 28, 1917, 459.

TABLE III

PROBABLE ERRORS OF THE LIMEN

Obs. *D.*

	Grouping by Series			
	By 25's	By 50's	By 100's	Total 200
1	.1187	.0862	.0539	.0378
2	.1262			
3	.0932	.0719		
4	.1116			
5	.1352	.0830	.0532	
6	.1036			
7	.1001	.0658		
8	.0947			
Average	.1104	.0742	.0535	.0378

Obs. *P.*

	Grouping by Series			
	By 25's	By 50's	By 100's	Total 200
1	.1168	.0882	0604	0369
2	.1283			
3	.1395	.0848		
4	.1057			
5	.1220	.0826	.0709	
6	.1123			
7	.1869	.1006		
8	.1244			
Average	.1294	.0891	.0656	.0369

Suppose again, to make the illustration more concrete, that we consider the probable correctness of an individual difference between D and P. In Table IV we have computed[11] the probable correctness of

TABLE IV

PROBABILITY OF DIFFERENCE

	Probable Correctness of Difference					
	Average Difference		Maximal Difference		Minimal Difference	
Series	$\frac{D}{P.E._D}$	P. C.	$\frac{D}{P.E._D}$	P. C.	$\frac{D}{P.E._D}$	P. C.
200	13.55	100.00				
100	8.84	100 00	11.77	100.00	6.14	100.00
50	6.27	100.00	8.17	100.00	2.64	96.25
25	4.45	99.75	7.45	100.00	.93	73.36

the difference between the limens of D and P when the entire 200 series are taken, and when the minimal, maximal, and average differences are taken for the groups of 100 series, 50 series, and 25 series. We find that the probable correctness is 100.00% ("mathematical certainty") for the difference when 200 series are taken, and for any difference, even the minimal, between limens based on 100 series. If but 50 series are taken, we have 100.00% probable correctness for the difference between the averages of every set of four limens in the case of the minimal difference (between D's 2nd 50, and P's 4th 50), however, the probable correctness is 96.25%: a highly significant value, although not "mathematical certainty." Twenty-five series give 100. 00% for the maximal differences, 99.86% for the averages, and only 73.36% for the minimal difference (between D's 4th 25 and P's 8th 25). If we regard 96% probable correctness as sufficiently significant (as most investigators would), we are justified in expecting that 50 series would be sufficient to establish the fact of an individual difference between D and P. Twenty-five series would usually give a difference of high probable correctness, yet not always, for the minimal difference is but 73%. The application to Fernberger's problem[12] is obvious; our individual difference is established by fifty series, not because practice-effect is considerably diminished, but because the number of observations attests the reliability of the indicated difference.

3. *The Approximation of the Actual Data to the Phi-Gamma Hypothesis.* Table V shows the sums of the squares of the deviations of the actual percentages from the theoretical percentages as determined under the Φ (γ)-hypothesis. The numbers, therefore, consti-

[11] The manner of computation of the values of Table IV as well as of the immediately preceding theoretical values is obvious from Boring, this JOURNAL, 27, 315-319.

[12] This JOURNAL, 27, 1916, 261 ff.

tute measures of the degree in which this hypothesis is realized in practice. The averages, for D, show that doubling the number of series tends approximately to halve the departure of the empirical data from the hypothesis. The same tendency is observable in the averages of P. The averages of the groups of 25, 50, and 100 series show a highly uniform ratio of decrease; here the averaging covers up the variations due to the unfavorable conditions already mentioned. It is clear, however, especially with D, that we approach the theoretical function as we increase the number of observations. This relationship suggests that the Φ (γ)-hypothesis is the correct hypothesis for these conditions, and that deviations from it are due in actual cases not to errors of theory but to errors of observation.[18]

The variability (M. V.) of these deviations also tends roughly to vary inversely with the number of the series. Two of the values for the groups of 25 are less than the value for the total group of 200 (D), although the average for the 25's is almost six times the value for the 200. For P the same relationship holds, although it is less extreme.

For D the Φ (γ)-hypothesis appears to be approached with practice. The departure of the second 100 from theory is only about one-eighth that of the first 100. Even when the errors of observation are increased by reduction of the number of the series to 50, the last 50 fit theory over five times more closely than the first 50. P's results, however, show exactly the opposite relation.

TABLE V

SUMS OF THE SQUARES OF THE DEVIATIONS OF THE ACTUAL FROM THE THEORETICAL PERCENTAGES

Obs. D.

	Grouping by Series			
	By 25's	By 50's	By 100's	Total 200
1	.012446	.025707	.007375	.002918
2	.070011			
3	.001276	.002172		
4	.004862			
5	.020106	.006046	.000921	
6	.002699			
7	.015358	.000459		
8	.009828			
Average	.017073	.008596	.004148	.002918
M.V.	.013992	.008555	.003227	

[18] Here we have a hint as to a method of separating errors of observation from errors of theory; *cf.* Urban, *Psychol. Rev.*, 17, 1910, 231 f.

Obs. *P*.

	Grouping by Series			
	By 25's	By 50's	By 100's	Total 200
1	.006310	.000199	.000537	.005683
2	.007635			
3	.024527	.003006		
4	.007560			
5	.025026	.019722	.005736	
6	.023411			
7	.030874	.005758		
8	010099			
Average	.016934	.007173	.003142	.005683
M.V.	.009031	.006275	.002607	

With *D* practice is the more effective of these two factors. We approximate theory more closely in the second 100 than in the entire 200; practice more than makes up for the reduction of the number of series to one-half. The fourth 50 actually fit theory about seven times more closely than do the entire 200. If approximation to theory were, as it appears to be for *D*, a measure of the elimination of errors of observation and hence of the reliability of data, then we should do well to take many series, and to discard the early ones as merely furnishing practice.

Unlike *D*, however, *P* departs, as we have seen, farthest from the hypothesis in the last quarter of his work. This result may mean, on the face of it, that the hypothesis is not ideal for *P*; more probably however, certain disturbing factors increased in effectiveness during the course of the experiment.[14]

Finally, we may note that the absolute size of these measures of the deviation of practice from theory is comparable with the size of the measures upon which Urban assumes that the $\Phi(\gamma)$ is a better hypothesis for lifted weights than is the arctan-hypothesis.[15] One-third of our values (when divided by 3, the number of observations by which the limen is overdetermined) are less than the average of Urban's values (when divided by 5, the amount of overdetermination in Urban's case).[16]

[14] The situation which finally resulted in P's departure from the university for military service appears to have unfitted him for observation; see above, p. 592.

[15] *Op. cit.*, 258.

[16] *Cf.* the formulae in W. W. Johnson, *Theory of Errors and Least Squares*, 1915, 108; Urban, *Arch. f. d. ges. Psychol.*, 16, 1909, 226.

XXXIX. The Effect of Absolute Brightness Upon Color Contrast

By Ruth L. Crane

Kirschmann[1] laid down the law that "simultaneous color-contrast is best when brightness-contrast is eliminated or reduced to a minimum."[2] This relationship, as Kirschmann pointed out, is implicit in Schmerler's earlier study.[3] Schmerler gives a table which shows that a "strong" contrast-effect occurs under conditions in which the brightness of the colored inducing field and of the grey field which undergoes induction are approximately equal; whereas the contrast-effect is "weak" when the one field is very much lighter or darker than the other.[4] Kirschmann tabulates the actual values of the brightnesses of gray disks (in degrees of Bk and W) which gave the "maximal value of contrast" with certain colored inducing fields.[5] His data are few, but the indication is that the relationship holds without regard to the saturation of the inducing field; fields of the same brightness but of different saturations induce maximal contrast upon fields of the same brightness, although the *amount* of the maximal effect does, naturally, depend on saturation. Neither Schmerler nor Kirschmann gives figures to show the manner in which the contrast-effect decreases when the contrasting field is made lighter or darker than the inducing field. Obviously, if we were to measure the contrast-effect of a constant inducing field, we could plot the amount of contrast-effect for varying brightnesses of a gray field, and could determine the nature of a function, in which the maximum would occur at the brightness of the inducing field. The form of this function constitutes a psychological problem.

Pretori and Sachs[6] measured the contrast-effect of a colored background upon a gray ring by determining how much of the color, complementary to the contrast-color, must be introduced into the ring in order just barely to neutralize the contrast-color. The results, on their face value, appear to contradict Kirschmann's law; hence we shall do well to examine them critically.

Both background and ring were made of rotating colored disks.[7] There were four experiments; in every one the background consisted of a color and black and white, and the ring of the same color (less of it, to kill the contrast) and black and white. The color-valence (C. V.) of a combination is measured directly by the number of degrees of color. The white-valence (W. V.) is measured by the number of degrees of white *plus* the white-equivalent of the black (in this case about 1.7% of the number of degrees of Bk) *plus* the white-equiv-

[1] A. Kirschmann, *Philos. Stud.*, 6, 1891, 417-491.

[2] Pp. 475, 491.

[3] B. Schmerler, *ibid.*, I, 1883, 379-416; esp. 387ff.

[4] *Cf.* Schmerler, 388 (Table), and Kirschmann, 475.

[5] P. 476.

[6] H. Pretori and M. Sachs, *Pflüger's Arch.*, 60, 1895, 71-90. This paper is summarized, a little obscurely, by J. H. Parsons, *Introduction to the Study of Colour Vision*, 1915, 264-266. (A confusing misstatement occurs p. 265, l. 28.)

[7] *Cf.* also L. J. Martin, *Am. J. Psychol.*, 24, 1913, 33f., who does not, however, mention Pretori and Sachs.

alent of the color (about 25% in the case of red). The value of the W. V. is a direct measure of the brightness of the color. The ratio of the C. V. to the W. V. is a measure of the "saturation" of the color. (These relationships are Hering's.) The results may be summarized as follows.

Exp.	Background			Ring		
	C.V.	W.V. = Brightness	$\frac{\text{C.V.}}{\text{W.V.}}$ = Saturation	C.V.	W.V. = Brightness	$\frac{\text{C.V.}}{\text{W.V.}}$ = Saturation
I	constant	constant	constant	increased (proportionally)	increased	constant
II-1	increased	constant	increased	constant	decreased	increased (proport. to incr. in bckgr.)
II-2	constant	increased	decreased	constant	increased	decreased (proport. to decr. in bckgr.)
II-3	increased (proportionally)	increased	constant	constant	constant	constant

In Exp. I the background was kept constant. The C. V. of the ring was increased arbitrarily; then the W. V. was increased until the contrast-color of the ring was just eliminated. The necessary increase of W. V. was about proportional to the increase of C. V.; hence the saturation remained constant. In Exp. II 1, the C. V. of the background was increased arbitrarily and the W. V. was kept constant; hence the saturation of the background increased. The C. V. of the ring was kept constant and the W. V. decreased until the contrast-color was eliminated. The resulting increase in saturation of the ring was approximately proportional to the increase of saturation of the background. In Exp. II 2, the C. V. of the background was kept constant and the W. V. was increased; hence the saturation was decreased. The C. V. of the ring was kept constant and the W. V. increased until the contrast-effect was just about to appear. The decrease in saturation proved to be very nearly proportional to the decrease in saturation of the background. Finally, in Exp. II 3, the saturation of the background was kept constant by increasing the C. V. and W. V. in a constant proportion. Under these circumstances the contrast-effect in the ring was eliminated without any considerable change in the ring.

These results appear to show that the amount of color-contrast is dependent upon the saturation of the inducing field and is independent of the relative brightnesses of the fields. A contrast-effect produced

by a constant saturation is neutralized by a constant saturation, even though the brightness of the ring be increased while the background remains constant (I) or the brightness of the background be increased while the ring remains constant (II 3). The contrast-effect of an increasing saturation is neutralized by a saturation which continues in the same proportion to it, even though the ring be continuously darkened with respect to the background (II 1). Does Kirschmann's law break down under these conditions?

The generalizations of the table are, however, only approximate; and the actual deviations show a trend that is in accordance with Kirschmann's finding. In all of Pretori and Sachs' cases the ring is darker than the background, and generally very much darker. Thus, in Exp. I, when the ring is brightened, it approaches the background in tint and should tend to have more color induced in it; the actual saturation necessary for the elimination of the contrast-color should therefore increase gradually. If we examine the data (pp. 79f.), we find that the saturations of the ring do increase somewhat, just as Kirschmann's law would have led us to expect. The courses of the saturations of the ring in the two cases are:

0.7, 0.9, 1.2, 1.3, 1.3, 1.3, 1.3;
and 0.4, 0.7, 0.9, 1.1, 1.2, 1.3, 1.3, 1.4, 1.4.

In Exp. II 1, the ring begins as darker than the background and is made still darker; a constant saturation of background should continuously induce less color. Thus we should expect, under Kirschmann's law, that the actual increase in saturation of the background would require something less than a proportional increase in saturation of the ring. And we find our expectation justified in the averages of the two cases (pp. 82f.):

When the background changes as	1.00	:	1.25	:	1.50,	
the ring changes as	1.00	:	1.07	:	1.17;	
and when the background changes as	1.00	:	1.50	:	2.00,	
the ring changes as	1.00	:	1.30	:	1.50.	

In Exp. II 2 the background and ring grow lighter together; hence we might expect proportionality between the saturation of background and ring. The actual data (p. 85) show a much closer proportionality than occurs in any other case.

When background changes as	1.00	:	0.75	:	0.50,
the ring changes as	1.00	:	0.77	:	0.57.

Finally, with the increase of brightness-contrast due to the lightening background of Exp. II 3, we should expect the necessary saturation of the ring to decrease slightly. The actual average decreases (pp. 87f.) are as 1.00 : 0.95 : 0.92 and as 1.00 : 0.90 : 0.87 : 0.92.

Pretori and Sachs thus substantiate Kirschmann indirectly and even furnish a hint of the form of the function[8] when the induced field is darker than the inducing.

Ebbinghaus[9] notes that approximately equal brightnesses of the contrasting field are necessary for maximal contrast. He explains the decreased contrast-effect on grays lighter than the inducing color by the desaturating effect of light gray (*cf.* Hering's relation of W. V. to saturation, above); and the decreased effect on dark grays

[8]The deviations in Exp. I are consistent with the data that we shall present later.

[9]H. Ebbinghaus, *Grundzüge der Psychologie*, I, 1905, 239.

as due to irradiation. Since different factors are operative at the two extremes, one might expect the function to be asymmetrical.

Recently Cook and Kunkel[10] have published data in which "the law of greatest color contrast when brightness contrast is eliminated seems to hold . . . only to a certain extent. It is apparently partially counteracted by another tendency, namely, for the lighter rings to suffer greater contrast effect than the darker ones. . . . The two laws. . . . sometimes work together and sometimes cut across each other." The authors are far from dogmatic about this second law or tendency; they suggest further experiments, and phrase the problem: "Do lighter surfaces suffer more color contrast effect than darker ones, under equal conditions of brightness contrast between the contrast-inducing and contrast-suffering surfaces?"

It is not obvious upon what aspect of their data Cook and Kunkel base this suggestion. They may mean that a given color tends to induce more color upon a lighter gray, or else that a lighter color tends to induce more color upon a gray of the same tint. In the first case, this second tendency would operate to make the function that occurs under Kirschmann's law asymmetrical. When rings darker than their backgrounds are lightened the two tendencies would be additive; when lighter rings are made still lighter the tendencies would be in opposition; and whether the function rose or fell would depend on the dominant tendency. If the tendency of Kirschmann's law were the more effectual, then the function would simply slope off more gradually for the light rings than it rose for the dark; if the tendency for lighter rings to suffer more contrast-effect were dominant, then the function might continue to rise for the lighter rings, though less rapidly than for the darker. In the second case, we should find the function symmetrical with respect to the tint of the inducing ground, but greater amounts of induced color would occur for the lighter grounds.

Cook and Kunkel's data provide some evidence for the first conclusion. Of their 18 cases (p. 19), 5 show a continuous increase in the amount of induced color when the brightness of the ring is increased, 6 show an increase followed by a decrease, and 7 are equivocal. When all the results are averaged, the tendency is toward continuous increase. Every function is, however, based upon four points only, and the differences are small; hence, as the authors themselves point out, we must accept general conclusions with reserve.

The alternate conclusion, namely, that lighter colors induce, upon grays of the same brightness, more contrast-color, seems, at first glance, to be established. Hering Y, for example, is over six times as bright (by the flicker method) as Hering R and induces over five times as many degrees of BG. The correlation between the average amounts of induced color (3 O's) and the flicker-brightnesses of inducing backgrounds is about 79%. We could not presumably expect a higher value when the saturations are uncontrolled. Hering Y is probably of poorer saturation than Hering R and loses on that account.

Cook and Kunkel measured amount of contrast by the total degrees of color necessary on the second color-mixer to match the induced color of the ring. The amount of colored paper in a color-combination, however, by no means measures the amount of color *seen*. White paper has a much greater desaturating effect than black.

[10] H. D. Cook and F. M. Kunkel, *Psychol. Rev. Monog.*, No. 96, 1916, 1-39; esp. 18f. 22, 39.

Hence 180°R + 180°Bk looks much redder than 180°R + 180° W, although the angular amount of R is the same. In Hering's terms—as we saw in our discussion of Pretori and Sachs—the amount of colored paper is one thing, the "color-valence;" the amount of color is another thing, the "saturation", and is the quotient of the C. V. by the W. V. (brightness). Cook and Kunkel deal with color-valences; Kirschmann was interested in the amount of color seen (*i. e.*, the saturation, if we grant the hypothesis that equal saturations, defined as above, appear equally colored). Cook and Kunkel do not give the data which permit the computation of the W. V.'s of their mixtures and hence of the saturations. The general indication of their data is that the increased contrast (C. V.) in both the cases we have discussed is roughly proportional to the increase in brightness (W. V.) upon which it depends; that is to say, the saturation (granting that Hering's relation holds approximately) does *not* tend to increase with lighter rings. In the first case, we may argue that the contrast-color (saturation) suffers as much from brightness-contrast in rings lighter than the inducing ground as it does in darker rings, but that more colored stimulus (C. V.) is required to produce a given amount of color (saturation) in the lighter rings. In the second case, we may urge that all colors of the same degree of saturation induce equal amounts of contrast-color in grays of the same brightness as the inducing color, but that lighter grays, which match the lighter colors in tint, require more C. V. in order that they shall appear equally colored.

Experimental

We have repeated Cook and Kunkel's experiment with various tints of a single color, with the intention of gaining more light on the proposed second law. The work was done in the Cornell Summer Session, 1917. There was time only for a single determination of every point; hence the work can be regarded as little more than preliminary.

We used three observers: Miss M. Cowdrick (*C*), Mr. H. D. Williams (*W*), and Dr. E. G. Boring (*B*).

We followed Titchener's general procedure[11], but made the ring by using three sizes of disks[12] We secured constant illumination by working in a dark-room with artificial daylight[13]. A single "day-lite" unit (200-watt Mazda Type-C lamp) was placed 70 cm. in front of the color mixers and slightly above them. The observer was seated 2 m. from the mixers and looked under the lamp. He could not see the light directly. The size of the disks and the distance between the two motors duplicated the dimensions of Cook and Kunkel (p. 12). A large gray exposure-screen, which obscured both disks and background, controlled the time of exposure. The disks were never seen except when in rotation. In the early stages of making a match the observer was allowed long exposures. He was compelled, however, to make his final judgment of equality with a brief exposure of approximately 1 sec.[14]

[11]E. B. Titchener, *Experimental Psychology*, I, i, 1901, 16, 19.

[12]Pretori and Sachs; Martin; *cf.* note 7 above.

[13]*Cf.* A. J. Brown Some Uses of Artificial Daylight in the Psychological Laboratory, *Am. J. of Psychol.*, 27, 1916, 427-429.

[14]A precaution which Cook and Kunkel did not observe, although they tried fixation *V.* pp. 11, 20f.; also the fourth conclusion, p. 39. On adaptation, *cf.* Titchener, *op. cit.*, I, ii, 33.

Ideally we should have selected as inducing backgrounds three reds of equal chroma and very different tints. We lacked time, however, to carry through a psychological method for the equation of the chromas; and we feared to trust that equal saturations, according to the Hering formula, would give subjectively equal chromas. Instead we selected a standard R of middle tint (S); two much lighter R's, approximately equal in tint (actually of equal W. V.), one slightly better and the other slightly poorer in chroma than S; and two darker R's of equal tint, one slightly better and the other slightly poorer than S. Later we added another pair of still lighter R's and another pair of still darker R's. We checked the subjective equality of tint and the just noticeable subjective difference of chroma by the consensus of our three observers. We used Hering R, baryta W, and velvet Bk papers. We determined the tint of the R by the method of constant stimuli (100 series, 5 stimulus pairs): 48W + 312Bk. (A flicker-photometer result is 57W + 303Bk.) Velvet Bk, under our conditions, had a light value of about .05 baryta W (Kirschmann photometer). From these values we could compute the W.V. and hence the saturation of every combination. The background for the matches were arranged in accordance with the W. V. of the inducing colors. In the description of the following nine inducing colors, D means much darker; d, darker; S, standard; l, lighter; L, much lighter; g, slightly better chroma than S; p, slightly poorer chroma than S; C. V., color-valence; W. V., white-valence; saturation, C. V./W. V.

			C.V.	W.V.	Saturation
1.	Dp:	60R + 2W + 298Bk.....	60	27	2.22
2.	Dg:	70R + 285Bk.....	70	27	2.78
3.	dp:	130R + 15W + 215Bk.....	130	49	2.65
4.	dg:	150R + 12W + 198Bk.....	150	49	3.06
5.	S:	180R + 24W + 156Bk.....	180	64	2.82
6.	lp:	250R + 33W + 77Bk.....	250	82	3.05
7.	lg.	270R + 30W + 60Bk.....	270	82	3.29
8.	Lp:	300R + 47W + 13Bk.....	300	102	2.94
9.	Lg:	315R + 45W	315	102	3.09

All nine colors were used with *W* and *C*. *B* worked with S and the extreme pairs only.

With every inducing color we began with a ring of 18°W and, after matching the contrast-color of the ring by the disks on the second mixer, increased the W in the ring by 30°; and so on, by 30° steps, until in two successive matches the observer required no color on the second motor.

The contrast-color of the ring was matched by baryta W, velvet Bk, Hering B, and Hering G. The C. V.'s were taken as the sum of the degrees of G + B. As the proportion of G to B was fairly constant, no great error was involved.[15] In computing the W. V. of the match of every ring we had to rely on flicker-photometer equations for B and G: G = 148 W + 212 Bk; B = 33 W + 327 Bk. Since our data are rough, any error involved in this method of photometry is probably not serious. The saturations of the induced contrast-color in every ring were computed from these values of C. V. and W. V.

[15]The av. ratios of G to B and their M. V.'s, where 10° or more of color were used, are: for *W*, 1.27 ± .15; for *C*, 1.16 ± .30; for B, 1.26 ± .18. Cook and Kunkel added degrees of G and B; p. 18.

The C. V.'s are shown in Table I; the saturations in Table II. The tendency in both cases is for the values to start, with the darkest ring, at a minimum, rise to a maximum, and then drop off to zero with the lighter rings. Hering R is a dark paper; hence we were unable to get a range of darker rings as great as the range of lighter rings. Our darkest ring (18° W + 342° Bk; W. V. = 35) was actually lighter than our darkest colors (Dg, Dp; W. V. = 27). If we had foreseen this difficulty we could have used a ring of 360° Bk (W. V. = 18) or possibly a lightless hole (W. V. = 0); but even these stimuli would not have given symmetry.[16]

TABLE I

COLOR-VALENCES

Obs.	Degrees of W in contr. ring	Inducing Colors								
		Dp	Dg	dp	dg	S	lp	lg	Lp	Lg
W	18	20	19	0	8	6	0	8	0	0
	48	0	7	22	23	26	24	28	15	15
	78	0	0	7	7	15	31	22	24	21
	108		0	0	3	0	15	18	22	34
	138			0	0	0	8	0	20	33
	168				0		0	0	20	13
	198						0		0	3
	228								0	0
	258									0
C	18	5	9	7	9	5	5	10	5	0
	48	5	4	16	12	19	22	17	19	15
	78	0	0	7	6	14	22	15	34	32
	108	0	0	0	3	11	19	14	35	35
	138			0	0	14	7	15	7	15
	168			0	0	11	0	13	0	5
	198					22	0	13	0	0
	228					0		9		0
	258							0		
B	18	15	11			28			0	15
	48	10	9			49			23	33
	78	0	3			44			46	55
	108	0	0			25			61	46
	138		0			33			64	63
	168					0			47	44
	198					0			0	21
	228								0	0
	258									0

[16]One can not overcome the difficulty by partial light-adaptation; such a procedure would give darker R's as well as darker Bk's. The only solution seems to be a lighter colored paper, say Hering G or Y.

TABLE II

SATURATIONS

Obs.	Degrees of W in contr. ring	Inducing Colors								
		Dp	Dg	dp	dg	S	lp	lg	Lp	Lg
W	18	.39	.37	0	.23	.23	0	.19	0	0
	48	0	.10	.30	.30	.36	.39	.45	.24	.22
	78	0	0	.07	.07	.16	.34	.37	.26	.23
	108		0	0	.02	0	.14	.15	.20	.30
	138			0	0	0	.06	0	.13	.23
	168				0		0	0	.10	.08
	198						0		0	.01
	228								0	0
	258									0
C	18	.11	.19	.17	.22	.14	.14	.26	.15	0
	48	.07	.05	.21	.17	.26	.33	.27	.32	.24
	78	0	0	.08	.07	.15	.26	.18	.38	.34
	108	0	0	0	.02	.09	.20	.12	.34	.30
	138			0	0	.10	.05	.12	.05	.12
	168			0	0	.06	0	.09	0	.03
	198					.10	0	.07	0	0
	228					0		.04		0
	258							0		
B	18	.33	.24			.64			0	.47
	48	.14	.12			.65			.35	.51
	78	0	.03			.42			.56	.60
	108	0	0			.21			.58	.46
	138		0			.21			.46	.46
	168					0			.28	.29
	198					0			0	.12
	228								0	0
	258									0

TABLE III

MAXIMAL COLOR-VALENCES AND SATURATIONS INDUCED BY DIFFERENT INDUCING COLORS

Inducing Color	Dp	Dg	dp	dg	S	lp	lg	Lp	Lg
W.V	27	27	49	49	64	82	82	102	102
Saturation	2.22	2.78	2.65	3.06	2.82	3.05	3.29	2.94	3.09
Maximal C.V. Observed:									
W	20	19	22	23	26	31	28	24	34
C	5	9	16	12	22	22	17	35	35
B	15	11			49			64	63

TABLE III—*Continued*

Maximal C.V. Computed:									
W	15	18	16	17	25	27	25	27	29
C	6	9	16	10	16	24	16	31	29
B	16	12			43			61	58
Maximal Saturation Observed:									
W	.39	.37	.30	.30	.36	.39	.45	.26	.30
C	.11	.19	.21	.22	.26	.33	.27	.38	.34
B	.33	.24			.65			.58	.60

Table III shows the maximal amounts of induction occurring for every inducing color. The observed maximal C. V.'s from Table I are first tabulated. In some cases, however, the data of Table I do not indicate clearly the amount of the maximum; the function is irregular, and we wished that all points might be brought to bear upon the amount and position of the maximum. Accordingly we smoothed out the curves by calculating, by the method of least squares, the most probable parabola; and in this way determined the computed maximal C. V.'s of Table III.[17] Finally, Table III gives the observed maximal saturations. These values are indicated unequivocally in Table II; hence it was not necessary to generalize the curve in accordance with an hypothesis.[18]

Table III shows that the maximal C. V.'s tend in general to increase with the brightness (W. V.) of the inducing color. The computed values, which are based on three to nine points instead of a single one, show this tendency more strikingly. Cook and Kunkel's law appears to hold with the C. V.'s. With the saturations, however, it does not hold. It is true that there is evident with the saturations some slight tendency for increase, but this tendency appears to be due to the differences in saturation of the inducing colors. The darker colors unfortunately turned out to be the less saturated. The correlations between the saturations of the inducing colors and the maximal induced saturations run about 60 to 70%.[19]

[17] The details of the computation can not be given here. We used the parabola, $y = Ax^2 + Bx + C$, because a preliminary investigation showed that it approximately fitted the average of the data if the extreme points were omitted. The normal equations are:

$$[x^4]\ A + [x^3]\ B + [x^2]\ C = [x^2y]$$
$$[x^3]\ A + [x^2]\ B + [x]\ C = [xy]$$
$$[x^2]\ A + [x]\ B + nC = [y]$$

Then the brightness of the ring suffering maximal contrast is $x_m = -B/2A$. The required maximal ordinate is $y_m = C - Ax_m^2$. The data for Dp and Dg do not show a maximum; hence for them we used the parabola, $y = Ax^2 + C$, where x_m is assumed 0, and $y_m = C$.

[18] If a parabola be passed through the three maximal points (*cf.* F. M. Urban, *Statistical Methods*, 1908, 124f.), the maximal values are not altered within our rough limits of precision.

[19] For *W* the correlation, r, = 10.2%; for *C*, r = 76.0%; for *B*, r = 59.0%. But if for *W* the two rather unreliable values for Dp and Dg be discarded, then his r = 61.8%.

Hence we may conclude that such significant variation of the saturations as exists is due to the saturation of the inducing colors and not to their tint.

Table IV gives the tints (W. V.'s) of the gray rings in which the maximal C. V.'s and saturations were induced. The points for the C. V.'s were found by the parabolic interpolation mentioned above. The points of maximal saturation were computed by an interpolation in which the bell-shaped curve of error was used as an hypothesis.[20] There are some wide deviations, but in general the tints undergoing maximal induction increase with the tints of the inducing colors, thus establishing approximately the principle of Kirschmann's law. The data for the saturations accord with the law about twi e as well as the data for the C. V.'s.[21]

TABLE IV

WHITE-VALENCES (TINTS) OF THE GRAY RINGS IN WHICH THE MAXIMAL COLOR-VALENCES AND SATURATIONS WERE INDUCED BY THE DIFFERENT INDUCING COLORS

Inducing Color.....	Dp	Dg	dp	dg	S	lp	lg	Lp	Lg
W.V.....	27	27	49	49	64	82	82	102	102
W.V. of Maximal C.V. (computed):									
W.....	< 35	< 35	75	68	73	88	83	125	119
C.....	35±	< 35	64	55	122	92	124	101	110
B.....	< 35	< 35			84			125	128
W.V. of Maximal Saturation (computed):									
W.....	< 35	< 35	64	56	63	65	72	86	108
C.....	< 35	< 35	57	35	61	74	38	82	91
B.....	< 35	< 35			48			114	90

Finally we note, in so far as our scanty data permit us, that there is no evidence of asymmetry of function about the point of maximal induction. If we arrange all our data with the maxima coincident (omitting Dp and Dg) and average the coincident values, we get for the C. V.'s an average function:

2, 7, 16, 27, 27, 16, 5, 1, 0;

and for the saturations an average function:

.19, .26, .36, .25, .13, .06, .02, .01.

We may conclude then:

(1) That light colors exhibit no marked tendency to induce more saturated contrast-colors than do dark colors;

[20] Both the C. V.-function and the saturation-function tend to be bell-shaped. We adjusted the saturations to the curve of error by omitting all zeros and assuming the maximum of the curve to be the observed maximum. We could not, therefore, use the curve of error with the C. V.'s, because with them we wished also to determine the amount of the maximum. The curve of error is, however, the more representative hypothesis and is the easier to apply. The normal equations are similar to those of the method of constant stimuli.

[21] When agreement is measured by the square root of the sums of the squares of the deviations.

(2) That light colors do induce contrast-colors of a greater color-valence, but that this greater color-valence is approximately proportional to the greater color-valence which, in relation to their saturation, the light inducing colors themselves possess;

(3) That maximal saturations are induced in grays of approximately the same brightness as the inducing color (Kirschmann's law), and that the induced saturation falls off to zero in an approximately symmetrical function with increased brightness-contrast in either direction;

(4) That, less accurately stated, maximal color-valences are induced in grays of approximately the same brightness as the inducing color;

(5) That equal saturations, determined as the quotient of color-valence by white-valence, are at least approximately equivalent to subjectively equal chromas, and may be used in a rough way to indicate equal chromas; and

(6) That rough functions, such as we have determined, can be made to yield more general results, if they are taken as wholes by adjustment, by the method of least squares, to some general hypothesis.

Ebbinghaus' explanation of Kirschmann's law, namely, that the fading out of color in the light grays is due to the desaturating effect of the white and the fading out in the dark grays to irradiation, does not appear, on these conclusions, to be valid. Ebbinghaus would lead one to expect that with the light gray rings the color-valence would remain about constant, the white-valence would increase, and the saturation would consequently decrease, eventually, no doubt, to a subliminal value. But we have seen that the color-valence falls off quite as rapidly as the white-valence increases. Furthermore, Ebbinghaus' supposition that different causes are operative at the two extremes of brightness-contrast would make an asymmetrical function probable; whereas our data indicate, though but roughly, that the function is symmetrical.

BOOK REVIEW

The life and work of George Sylvester Morris. By R. M. WENLEY. New York, Macmillan Co., 1917. 332 p.

The author is the successor of Professor Morris, who died twenty-five years ago, and this book is a labor of love. The author has taken endless pains to investigate everything connected with the subject of this memoir. A more exhaustive biography, and we may add a more appreciative one, has rarely been written. George Morris was a pioneer student of the history of philosophy in this country, a careful though not so very voluminous author, a musician of rare talent, who throughout his life gave great attention to this art, the translator of "Ueberweg," to which he added a great deal of material of his own. He might be in a new sense called a spiritual man. The Hegelism of his earlier and the Kantianism of his later life he had made so intimate a part of his own personality that it was very hard for him to discuss such themes with those whose standpoint differed from his own. To have traced the Morris lines back to the Pilgrims, to have dug up the details of his New England home, school and college life, early manhood, his experiences in the war, at Dartmouth, at Union Theological Seminary, at John Hopkins and Michigan, where most of his later life was spent, to have traced the origin, transition and final stage of his intellectual history and to have depicted the man and teacher so vividly, is a real service to the history of culture in this country. One can truly say that of all the many good fortunes that could befall such a man, the greatest is to have so worthy, eminent and loyal a biographer. Morris himself was naturally modest and retiring. He was in some sense an esthetic soul, who loved philosophy because of the personal satisfaction he derived from this study. Moreover, he lived at a time when in this country his studies met with very scant appreciation, save by the few, so that much of the best that he did and wrote had already begun to be forgotten, and it is a splendid act of mere justice, to say the least that can be said of it, to set his life and doctrine forth in the new, fresh way in whcih they are here presented. Possibly (and this is the only criticism that anyone could make of his work) the author at times takes too much pains and goes into too minute details, e. g., concerning Morris early life and relatives. But in a work written in the environment in which Morris so long lived, and in closest contact with the surviving members of his family, as it was, this cannot be called a blemish. The writer of this note cannot recall the name of a single American thinker who has had so splendid a biography. Indeed, this is so good that the name of Morris will always be associated with that of Wenley. The book ought to inspire others who have the now rather dwindling faculty of appreciation, to give us similar memoirs of James, Royce, Münsterberg, Charles Pierce, and perhaps we might add William T. Harris; but nothing of any of these or others who might be named has ever been attempted on such a scale.

BOOK NOTES

General types of superior men. By Osias L. Schwarz. Boston, Richard G. Badger, 1916. 435 p.

This is a philosophical, psychological study of genius, talent and Philistinism in their bearings upon human society and its struggles for a better social order. It has a preface by Jack London and an introductory letter from Max Nordau. The main topics are, genius, talent, superior and average minds, adaptation, heredity and variability, origins and causes, conditions and incentives, types of superior men, intellectual hierarchy, classification, creative, affective, striving life, influence on the masses, affectation, normality. Max Nordau writes that the book is teeming with ideas but still more seething with feelings. It is vehement, preaching in the Old-Testament, prophetic style, abrupt, fitful, violent, and the study of genius is really a pretext for invective against the average man, who is in fact an average beast. The author does not stop to prove and Nordau says that his picture of real society, which is probably American, is ghastly and appalling. Nordau tells him his command of English is wonderful.

The fundus oculi of birds, especially as viewed by the ophthalmoscope. A study in comparative anatomy and physiology. By Casey Albert Wood. Chicago, Lakeside Press, 1917. 180 p.

This impressive quarto volume begins with a summary of conclusions, bibliography, and a review of the anatomy and physiology of the organs and tissues seen in the fundus. The author next gives us an outline of ophthalmoscopy, and then proceeds to describe his application of its methods to the fundus of living birds, the eye-ground in general, the pecten and optic disc, the macular regions, foveal blood-vessels, nerve fibres, choroid and retina. He has also succeeded in giving us some very good photographs of the fundus in living birds. An interesting section describes the effects of domestication upon it. He tells us how it differs in different orders of birds, and how it may be used as a basis of classification; discusses the relations between the reptilian and avian fundi. The text itself is illustrated by 145 cuts, and to these are appended 61 full-page colored paintings.

Nichiren, the Buddhist prophet. By Masaharu Anesaki. Cambridge, Harvard University Press, 1916. 160 p.

Religious psychology has of late been extended by the development of considerable new material, either the expressions or the studies of strong personalities. The author was encouraged to write this book by the late Professor Royce. The material is remarkably copious, considering that this great Buddhistic reformer lived in the thirteenth century, but this is partly due to the revival of his teachings and spirit in modern Japan. The first chapter describes his time; the second, his birth, studies, conversion, and the Lotus of Truth. Then in successive chapters follow his public appearance and persecution; an interlude and a narrow escape; the threatening Mongol invasion and the sentence of death; the exile in Sado and the ripening of

Nichiren's faith in his mission; the climax of his life, the graphic representation of the supreme being; release and retirement; a paradise on earth; silent prayer and anxious watching; the last stage of his life and his death. To this is appended a chapter on the Buddhist conception of reality.

Science and learning in France; with a survey of opportunities for American students in French Universities. An appreciation by American Scholars. Society for American Fellowships in French Universities, 1917. 454 p.

This is a coöperative volume designed to show Americans the contributions of France in all branches of scientific knowledge, and to show her status in the forefront of the world's progress, and especially to give American students information as to graduate work in France. Each chapter (and there are over a score of them, some with various sub-divisions) takes up a particular topic, beginning with anthropology, archaeology, astronomy, etc., and gives briefly its history and prospects. President Charles W. Eliot and Dr. George E. Hale write introductions, and then follow the contributions of some two-score authors, with a long list of some thirty double-column pages of sponsors. It is designed to be a token of national homage on the part of America to France. While most heartily commending the purpose of such a work, it must be admitted that the chapters on the different topics are not, as a whole, very luminous. Some of them particularly are very perfunctory, superficial, ill-informed, and do scant justice to their subject. A great deal of the space of most is devoted to the great men of the past, and in the present writer's estimation too little attention is given to the actual present-day opportunities. It is doubtful whether this book would really contribute much in the way of either informing or inclining young graduates to go to France.

The growth of medicine from the earliest times to about 1800. By Albert H. Buck. New Haven, Yale University Press, 1917. 582 p.

The writer regrets that most medical schools give no teaching in the history of medicine but thinks two good reasons are the newness of the country and the few and rather too scientific character of texts. The latter trouble he seeks to obviate, and for those wanting something more exhaustive he refers to a more comprehensive work by Max Neuberger, of which two volumes have already appeared. He also refers to Haeser. The preface makes no mention of Sprengel's voluminous work in seven volumes, and although it is included in the author's literary references, he seems to have made very little use of it, and from the standpoint of the present reviewer he has hardly done justice to the Arabic influences in medicine. The chapters are divided into three groups, ancient, mediaeval and renaissance. The last or fourty-third chapter, describes the first appearance of syphilis in Europe.

The sex worship and symbolism of primitive races. By Sanger Brown II. Boston, Richard G. Badger, 1916. 145 p.

This is an interesting epitome of the main points and authors, old and new, in this field, from Jennings, Knight, Inman and Spencer, down to Frazer, Howitt and Miss Harrison. It contains four chapters, on simple sex worship, symbolism, sun myths, mysteries and decadent sex worship, and interpretations. The book is a very convenient epitome. The chief criticism of it, however, is that it seems to have

been written almost from start to finish in a pre-Freudian age. Only in the latter part of the book do we learn that the author has heard of this epoch-making man and his group of co-workers in a line in which this book really helps us on.

Group theories of religion and the individual. By CLEMENT C. J. WEBB. New York, Macmillan Co. (c. 1916). 208 p.

This work is devoted to an explanation of Durkheim and Lévy Bruhl, and as these views are very much in the forefront of discussion nowadays, this resumé is most opportune. There is a good deal of exposition of Durkheim, which is well, although some would perhaps wish that there had been more of this and less of the criticism of Mr. Webb. The chief topics are, the laws of contradiction and participation; Durkheim's definition of religion; criticism of his social theories of it; the social theory of categories; of pre-logical mentality; philophical basis of the theories of the sociologists; Durkheim's philosophy of religion; group theories and individual theories of religion.

Comparative religion; its adjuncts and allies. By LOUIS HENRY JORDAN. Oxford University Press, 1915. 575 p.

Part I. disucsses the avenues of approach, (1) anthropology, (2) ethnology, (3) sociology, (4) archaeology, (5) mythology, (6) philology, (7) psychology, (8) the history of religions, divided into special groups. Part II. the transition, describes the evolution of scientific method, apologetic treatises, translations of sacred texts, transactions of congresses, societies, encyclopedias, etc., special works, periodical centers of study. Part III. discusses comparative religion, its restricted idea and its legitimate scope. This is the most comprehensive attempt to depict the rise, sources, transitions, capacities and issues of this great department which does not appear now to be growing rapidly.

Gleanings from old Shaker journals. Compiled by CLARA ENDICOTT SEARS. Boston, Houghton Mifflin Co., 1916. 298 p.

The Shaker village at Harvard, Massachusetts, is unique because it was the headquarters of Mother Ann Lee, when she was spreading her gospel through the eastern states in the eighteenth century. All this is of great psychological interest. The wall of reserve has hitherto made the Shakers almost inaccessible, but the old antagonism between them and the world has now pretty well died out, as have the religious excesses of the old days. Now they are peaceful, honest, and affectionately esteemed. The first few chapters deal very largely with Ann Lee and her associates, and the later chapters bring the story down to the present time. Altogether it is a very interesting study, well worth while.

The spiritual ascent of man. By W. TUDOR JONES. New York, G. P. Putnam's Sons, 1917. 247 p.

This book seeks to bring the best philosophical thought of the time within the range of the ordinary reader, and is addressed to Englishmen. The author wants to create an interest in things of the spirit in the average man, believes there is no limit to the possibility of spiritual development, that the ideal is close at hand, and the divine is possible, life cannot be reduced to matter. The chief chapters treat of the scope and limit of science, matter and life, body and mind, the intellect and nutrition, the "is" and the "ought," values, the nature of the spirit, conception of God and Christianity.

Is civilization a disease? By STANTON COIT. Boston, Houghton, Mifflin Co., 1917. 136 p.

The question raised by this book has been often put before, and we have even of late heard the question discussed whether Christianity is a disease, unethical, bad or wrong. Edward Carpenter long ago published a work, once widely read, entitled "Civilization, Its Cause and Cure." The author stresses the gap between Christ and his modern worshipers. The main point, on which this work is rather sentimental, and not a very scholarly group of aphorisms, is that conventions—business, religion—of modern life do not fit man's nature and must be moulted, and he must make a new start.

Rest days: a study in early life and morality. By HUTTON WEBSTER. New York, Macmillan Co., 1916. 325 p.

This is a very interesting and learned anthropological study of the observance of days of abstinence, quiescence, often due to taboos. These are placed on days and at critical epochs by different races, also after a death. Then come chapters on holy-days, market-days, lunar superstitions and festivals, calendars and the week, Babylonian evil days, the Hebrew Sabbath, and unlucky days. The discussion of all these topics is not only learned, with countless references to original authorities, but is broad and philosophical.

Bells and bell lore; church bells of Amounderness and the Archdeaconry of Lancaster. By T. HARRISON MYRES. Preston, Guardian Printing Works, 1916. 112 p.

This fascinating theme is treated with great detail. The material is divided into two parts. The first is the general history of bells in different countries and cities, and the origin of certain customs, while the second part is occupied chiefly with accounts of bells in different English churches, together with traditions connected with them. The book is illustrated by many small cuts and a number of full-page illustrations and infolds. It it a work of details with little or no attempt at generalization.

Modern man and his forerunners; a short study of the human species living and extinct. By H. G. F. SPURRELL. London, G. Bell and Sons, 1917. 192 p.

This is an interesting and timely compilation. The author first lays down some general principles of anthropology and discusses the zoological position of man, extinct species and races of man and their culture, the growth of human powers and habits from the neolithic age, the origins of civilization, its growth and spread, and finally man to-day.

The way to Nirvana; six lectures on ancient Buddhism as a discipline of salvation. Hibbert Lectures, Manchester College, Oxford, February-April, 1916. By L. DE LA VALLÉE ROUSSIN. Cambridge, University Press, 1917. 172 p.

This work is in six chapters, (1) Origins of the Indian Disciplines of Salvation; (2) the Buddhist Soul; (3) Buddhist Definition of Karman; (4) The Doctrine of Karman and Transmigration, Cosmogony, Theogony; (5) Nirvāna; (6) The path to Nirvāna.

The holiness of Pascal. By H. F. STEWART. (The Hulsean Lectures, 1914-15). Cambridge, University Press, 1915. 145 p.

These lectures are first, biographical; second, Pascal in controversy; third, his doctrinal system; and fourth, his personal religion.

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